NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VIII. March, 1894. No. 3.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

QUARTERLY MEETING.

PARKER HOUSE, BOSTON, MASS., December 13, 1893.

The following members and guests were present:

MEMBERS.

Everett L. Abbott, New York City; Charles H. Baldwin, Boston, Mass.; Lewis M. Bancroft, Reading, Mass.; George E. Batchelder, Worcester, Mass.; Joseph E. Beals, Middleboro, Mass.; Nathan B. Bickford, Boston, Mass.; William R. Billings, Taunton, Mass.; Dexter Brackett, Boston, Mass.; Arthur W. F. Brown, Fitchburg, Mass.; George F. Chace, Taunton, Mass.; E. J. Chadbourne, Boston, Mass.; Charles E. Chandler, Norwich, Conn.; John C. Chase, Wilmington, N. C.; William F. Codd, Nantucket, Mass.; Freeman C. Coffin, Boston, Mass.; R. C. P. Coggeshall, New Bedford, Mass.; H. W. Conant, Gardner, Mass.; Byron I. Cook, Woonsocket, R. I.; George E. Evans, Boston, Mass.; B. R. Felton, Marlboro, Mass.; Desmond FitzGerald, Boston, Mass.; F. P. Forbes, Brookline, Mass.; Frank L. Fuller, Boston, Mass.; George W. Fuller, Lawrence, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; J. A. Gould, Jr., Boston, Mass.; E. H. Gowing, Boston, Mass.; Richard A. Hale, Lawrence, Mass.; John L. Harrington, Cambridge, Mass.; John Harris, Waltham, Mass.; John C. Haskell, Lynn, Mass.; V. C. Hastings, Concord, N. H.; Allen Hazen, Lawrence, Mass.; Horace G. Holden, Nashua, N. H.; Patrick Kieran, Fall River, Mass.; George A. Kimball, Boston, Mass.; Thomas C. Lovell, Fitchburg, Mass.; William J. Luther, Attleboro, Mass.; W. E. McClintock, Boston, Mass.; William McNally, Marlboro, Mass.; James W. Morse, Natick, Mass.; Hiram Nevons, Cambridge, Mass.; Albert F. Noyes, Boston, Mass.; Weaver Osborn, Fall River, Mass.; George S. Rice, Boston, Mass.; Walter

H. Richards, New London, Conn.; George J. Ries, Weymouth Centre, Mass.; J. W. Ringrose, New Britain, Conn.; Henry W. Rogers, Haverhill, Mass.; John D. Shippee, Holliston, Mass.; George A. Stacy, Marlboro, Mass.; William W. Starr, Jr., Bridgeport, Conn.; Edwin A. Taylor, Boston, Mass.; Lucian A. Taylor, Boston, Mass.; Robert J. Thomas, Lowell, Mass.; M. M. Tidd, Boston, Mass.; W. H. Vaughn, Wellesley Hills, Mass.; Charles K. Walker, Manchester, N. H.; H. A. Warren, St. Albans, Vt.; John C. Whitney, West Newton, Mass.; Horace B. Winship, Norwich, Conn.; George E. Winslow, Waltham, Mass., James M. Betton, Boston, Mass.; E. L. Ross, Chapman Valve Mfg. Co., Indian Orchard, Mass.; M. H. Crawford, Boston, Mass.; F. H. Hayes, Deane Steam Pump Co., Holyoke, Mass.; A. H. Davis, William H. Gallison, Boston, Mass.; J. A. Tilden, Hersey Mfg. Co., South Boston, Mass.; William d'H. Washington, The Hydraulic Construction Co., New York; Henry F. Jenks, Pawtucket, R. I.; S. V. Adams, Peet Valve Co., Boston, Mass.; William J. Ranton, Syracuse, N.Y.; H. H. Kinsey, Rensselaer Mfg. Co., Troy, N. Y.; Mr. Seamans, Perrin, Seamans & Co., Boston, Mass.; I. W. Dodge, Standard Thermometer Co., Boston, Mass.; H. C. Folger, secretary Thomson Meter Co., Brooklyn, N. Y.; G. H. Carr, Union Water Meter Co., Worcester, Mass.; Jesse Garrett, R. D. Wood & Co., Philadelphia, Penn.

GUESTS.

John M. Burleigh, South Berwick, Me.; D. W. Darling, Worcester, Mass.; Carlton Davis, Newton, Mass.; Loring H. Farnam, Boston, Mass.; Harry Gould, Boston, Mass.; F. B. Johnson, Waltham, Mass.; C.W. Mann, Methuen, Mass.; P. McCabe, New Britain, Conn.; J. J. Moore, Hingham, Mass.; S. H. Taylor, New Bedford, Mass.

The following new members were elected:

RESIDENT ACTIVE.

W. L. Blossom, Civil Engineer, Boston, Mass.; John M. Burleigh, Supt., South Berwick, Me.; Frank L. Fales, Civil Engineer, Lawrence, Mass.; Loring N. Farnham, Civil Engineer, Boston, Mass.; Henry B. Wood, Engineer Street Department, Boston, Mass.

NON-RESIDENT ACTIVE.

Michael A. Connell, Supt. St. Hyacinth, P. Q.; H. C. Landon, Civil Engineer, Little Falls, N. Y.; J. A. Marion, Civil Engineer, Montreal, Can.; D. S. Merritt, Supt., Tarrytown, N. Y.; Melnor P. Paret, Civil Engineer, Baltimore, Md.; Vaughan M. Roberts, Civil Engineer, Toronto, Can.; J. Waldo Smith, Civil Engineer, Montclair, N. J.; Jay M. Whitham, Hydraulic Engineer, Philadelphia, Pa.

ASSOCIATE.

The Edw. P. Allis Co., Pumping Engines, Milwaukee, Wis.
F. B. Hawkins, Cast Iron Pipe, New York City.
H. B. Ternby, Agent Repanno Chemical Co., Boston, Mass.

Mr. F. F. Forbes, Superintendent of the Brookline Water Works, gave a description of the covered reservoir at Brookline.

Mr. George E. Winslow, Superintendent, Waltham, read a paper giving a general description of the Waltham source of supply, and he was followed by Mr. F. P. Johnson, City Engineer of Waltham, who gave an account of the work of covering the basin and well. The papers were discussed by Mr. Fuller, Mr. Noyes, Mr. Johnson, Mr. Forbes, Mr. Walker, Mr. Tidd, Mr. Coffin and Mr. FitzGerald.

Adjourned.

ADJOURNED MEETING.

YOUNG'S HOTEL, BOSTON, MASS., January 10, 1894.

The following members and guests were present:

MEMBERS.

Everett L. Abbott, New York City; Charles H. Baldwin, Boston, Mass.; George E. Bachelder, Worcester, Mass.; James E. Beals, Middleboro, Mass.; William R. Billings, Taunton, Mass.; George Bowers, Lowell, Mass.; Dexter Brackett, Boston, Mass.; Arthur W. F. Brown, Fitchburg, Mass.; John M. Burleigh, South Berwick, Me.; John T. Cavanagh, Quincy, Mass.; George F. Chace, Taunton, Mass.; John C. Chase, Derry, N. H.; R. C. P. Coggeshall, New Bedford, Mass.; Byron I. Cook, Woonsocket, R. I.; George K. Crandall, New London, Conn.; Edwin Darling, Pawtucket, R. I.; Horace L. Eaton, Somerville, Mass.; John W. Ellis, Woonsocket, R. I.; Loring N. Farnham, Boston, Mass.; B. R. Felton, Marlboro, Mass.; F. F. Forbes, Brookline, Mass.; Z. R. Forbes, Brookline, Mass.; Frank L. Fuller, Boston, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; E. H. Gowing, Boston, Mass.; John C. Haskell, Lynn, Mass.; Louis Hawes, Boston, Mass.; Clemens Herschel, New York City; Horace G. Holden, Nashua, N. H.; Joseph L. Kenney, Lewiston, Me.; E. W. Kent, Woonsocket, R. I.; Willard Kent, Woonsocket, R. I.; Patrick Kieran, Fall River, Mass.; George A. Kimball, Boston, Mass.; Thomas C. Lovell, Fitchburg, Mass.; W. E. McClintock, Boston, Mass.; D. S. Merritt, Tarrytown, N.Y.; Frank L. Northrop, Milford, Mass.; Albert F. Noyes, Boston, Mass.; Edward H. Phipps, New Haven, Conn.; Dwight Porter, Boston, Mass.; Waldo E. Ramson, Uxbridge, Mass.; Walter H. Richards, New London, Conn.; George J. Ries, Weymouth Centre, Mass.; George O. Saunders, Hudson, N. H.; F. J. Shepard, Derry, N. H.; George A Stacy, Marlborough, Mass.; Frederick P. Stearns, Boston, Mass.; Lucian A. Taylor, Boston, Mass.; Robert J. Thomas, Lowell, Mass.; M. M. Tidd, Boston, Mass.; W. H. Vaughn, Wellesley Hills, Mass.; Charles K. Walker, Manchester, N. H.; Joseph Wallers, Fall River, Mass.; Horace B. Winship, Norwich, Conn.; George E. Winslow, Waltham, Mass.; E.

Worthington, Jr., Boston, Mass.; A. H. Broderick, Chadwick Lead Works, Boston, Mass.; E. L. Ross, Chapman Valve Mfg. Co., Indian Orchard, Mass.; M. H. Crawford, Boston, Mass.; Charles H. Eglee, Flushing, N. Y.; A. H. Davis, William H. Gallison, Boston, Mass.; J. E. Spofford, Hersey Mfg. Co., South Boston, Mass.; Henry F. Jenks, Pawtucket, R. I.; S. V. Adams, Peet Valve Co., Boston, Mass.; H. L. Bond, Perrin, Seamans & Co.; Boston, Mass.; Wilmer Reed, Burlington, N. J.; I.W. Dodge, Standard Thermometer Co., Boston, Mass.; E. J. Snow, Thomson Meter Co., Brooklyn, N. Y.; J. P. K. Otis and G. H. Carr, Union Water Meter Co., Worcester, Mass.; E. H. Rice, Walworth Mfg. Co., Boston, Mass.; Jesse Garrett, R. D. Wood & Co., Philadelphia, Pa.; H. A. Gorham, secretary The George Woodman Co., Boston, Mass.; H. B. Ternby, Boston, Mass.

GUESTS.

A. A. Blossom, Salem, Mass.; B. Bourne, Boston, Mass.; E. W. Bush, New London, Conn.; L. E. Daboll, New London, Conn.; D.W. Darling, Worcester, Mass.; H. P. Gallup, Ashmont, Mass.; J. M. Hetherton, Jr., New York City; Mr. Moore, Boston, Mass.; F. S. Newcomb, New London, Conn.; T. P. Nichols, Lynn, Mass.; Thomas H. Rogers, Nashua, N. H.; J.V. Reht, Peabody, Mass.; F. A. Snow, Providence, R. I.; S. H. Taylor, New Bedford, Mass.; A. B. Tower, Holyoke. Mass.; William F. Williams, New Bedford, Mass.

The Secretary presented applications for membership from the following named gentlemen, who were elected:

RESIDENT ACTIVE MEMBERS.

Theodore C. Bates, Water Commissioner, North Brookfield, Mass.; Francis Batcheller, Water Commissioner, North Brookfield, Mass.; Frank A. Barber, Civil Engineer, Brockton, Mass.; L. E. Daboll, Superintendent, New London, Conn.; Sidney G. Walker, Boston, Mass.; William S. Johnson, Civil Engineer, Brockton, Mass.; E. W. Clark, Civil Engineer, Jamaica Plain, Mass.; T. P. Nichols, Member Water Board, Lynn, Mass.

ASSOCIATE MEMBERSHIP.

Franklin A. Snow, Civil Engineer and Contractor, Providence, R. I.; William A. Harris, Selling Agent, Pratt & Cady Co., Hartford, Conn.

The President announced that the Executive Committee had voted to hold the next annual convention at Boston in June.

Mr. L. A. Taylor opened the discussion upon the subject, "The Construction of Reservoir Embankments," describing the reconstruction of a dam for the Worcester Water Works, on Lynde Brook. The subject was further discussed by Messrs. Darling, Freeman, Brackett, Tidd and Fuller. Mr. Freeman gave an account of the circumstances and the causes of the break in the Portland, Me., Reservoir, and Mr. Brackett explained how the repairs were made.

Experience papers were presented by Mr. John C. Chase on "A Cheaply Constructed Covered Reservoir;" and by Mr. George A. Kimball on "A Method of Recording the Location of Water Mains and Services."

Adjourned.

"COVERED RESERVOIR AT BROOKLINE, MASS."

BY

F. F. FORBES, SUPERINTENDENT.

(Read December 13, 1893.)

It is not my purpose in this short paper to touch on the history of covered reservoirs now in use in various parts of the world, or those which existed in old Roman times, for we all are more or less familiar with their construction; but rather to confine myself to a description of the covered reservoir in Brookline, and to a recital of some ideas which came to my mind whilst engaged in its construction, and also from studies of the subject in a general way.

It will not take one long to discover that a covered reservoir differs widely in most of its details from an open one. Also that certain problems connected with all hydraulic work will demand here much more care and attention.

Again, the cost of the class of reservoirs now under consideration must be large, consequently their size will be reduced to the minimum. And it follows that the smaller the capacity the greater and more sudden must be the fluctuation of the water in it. A fluctuation so great that most of the open reservoirs as now constructed would be ruined by it in a short time. This item forms one of the problems just alluded to.

It is therefore plain that a covered reservoir must be built so thoroughly and well that it can be filled today and emptied tomorrow without injury to itself, and so on indefinitely. When we bear these facts in mind, the subject becomes a difficult one, and we see that not only should the design be carefully studied, but that it is equally important that the work should be done in the most faithful manner.

The description of the reservoir in Brookline and the way in which we attempted to build a lasting structure, is as follows:

The reservoir is simply a masonry chamber 91.33 feet square at the bottom, and 94.00 feet square at the springing line of the covering arches; with a depth of 19.2 feet from the overflow, giving a capacity of 1,200,000 gallons.

The batter of the walls is 1.34 feet. The roof is formed of a series of brick arches, and the bottom is covered with cement concrete. The inside of the walls are plastered with Portland cement. It will thus be seen that the whole inside of the reservoir can be cleaned as completely as an earthen dish.

No gate chamber is connected with the reservoir; the inlet pipe, which also serves as an outlet, and the drain pipe enter the reservoir directly through the walls. The gates controlling these pipes are 500 feet distant at a point where the pipes come to the usual grade for street mains.

The overflow discharges into the open reservoir immediately adjoining. The side walls are 9½ feet and 8½ feet thick at bottom, and are built of

Roxbury pudding stone, laid in American cement mortar. They extend 3½ feet below the bottom of the reservoir, and are started on 4 inches of American cement concrete. Great care was used to make certain that no spaces should be left in the wall, and to insure this, many barrels of cement in the form of thin gruel were poured down around the larger stone, and in fact it was the usual custom to grout thoroughly each course of stone.

Of course the contractor rather objected to such a lavish use of cement, but as the specifications required absolutely no voids in the stone work, there was little room for complaint.

The pier foundations, 3½ feet square, built also of Roxbury pudding stone, were started on a Porland cement concrete base 5 feet square and 4 inches thick.

The piers, 2 feet square, were built of hard burnt brick laid in American cement mortar to a point below the skew-back for the lintels, and above this in Portland cement mortar.

It might be stated here that all cement used above the foundation except that in the walls, was made of Portland cement.

The lintels or carrying arches are 24 inches wide and 8 inches thick. They have a span of 10 feet and a rise of 1 foot.

The skew-back for the covering arches is formed of one course of brick laid on top of the lintels. The covering arches have the same span and rise as the arch which supports them, and are composed of 4 inches of brick and 4 inches Portland cement concrete.

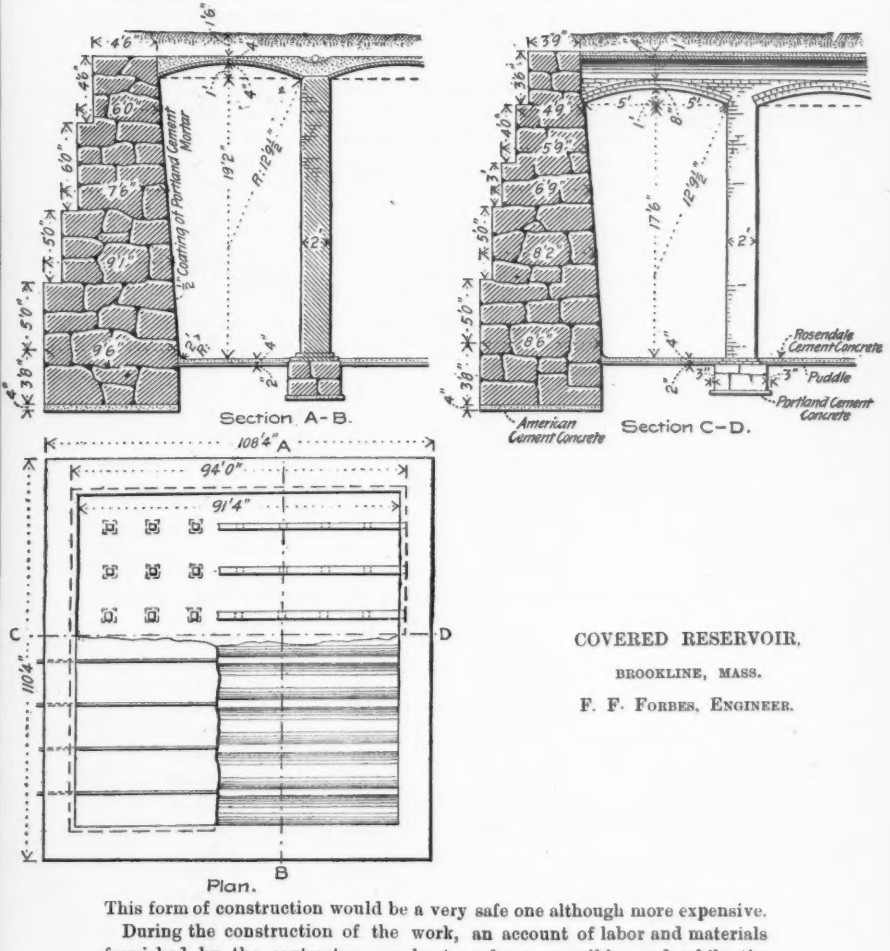
Suitable drains are provided to carry off all water from rain or snow which may reach these arches, and they are protected from frost by a covering of 18 inches of loam.

About 6 inches of clay puddle was placed back of the walls. The embankments were rolled or rammed in the usual manner. The bottom of the reservoir was first covered with 4 inches of clay puddle, and on this was placed 4 inches of American cement concrete. Great care was necessary not to mix the concrete and the puddle ; the concrete was successfully laid however, being placed in position with shovels and smoothed off with the same tool. No ramming as usually done was allowed, for fear of driving the soft clay up through the concrete. The concrete was also brought up around the sides of the walls and piers for a few inches.

As before stated, the inside of the walls were plastered with Portland cement. A difficult task in our case, as the reservoir was mostly in excavation and adjoining the open reservoir, consequently wholly below the natural water line in the ground. In such cases it would be well, I think, to keep the plastering in advance of the earth embankment on the outside. Perhaps later going over the walls with a thick wash of Portland cement. However the plastering was well done, as the later examination proved.

To determine whether or not the reservoir leaked to any appreciable degree, it was shut off last summer when nearly full, for 24 hours. After this length of time we could detect no difference of the level of the water, with the means we had for measuring. We concluded therefore, that the reservoir is practically tight.

The idea has occurred to me that in excavations where a good foundation for the pier could not easily be obtained, or there was danger of the bottom concrete being thrown up when the reservoir should be suddenly drawn down, the bottom could be an exact copy of the masonry of the top reversed.



COVERED RESERVOIR,

BROOKLINE, MASS.

F. F. FORBES, ENGINEER.

This form of construction would be a very safe one although more expensive.

During the construction of the work, an account of labor and materials furnished by the contractor was kept as far as possible, and while the amounts given are not absolutely correct, it is probable that they are not far

out of the way. I will now give the amount of work done, and the contract price for the same, immediately followed by labor and material account just mentioned. You will notice that the item of earth work is a large one. We unexpectedly found a bog hole in the bottom of the reservoir, which had been covered over with good material when the open reservoir was built, and was not discovered by the test pits. In consequence of this we had to borrow some suitable material for the embankments. This increased the amount of excavation by nearly 3,000 cubic yards.

Cubic yards of earth excavation		7,480	at $ .70	$5,236.00
" stone masonry in walls	2395.4			
" " under piers	51.2			
		2,446.6	4.50	11,011.50
" brick work in Portland cement		173	19.50	3,457 35
" brick work in American cement		142	18.00	2,556 00
" concrete in Portland cement		280	6.95	1,946.00
" concrete in American cement		145.5	5.45	809.32
" puddle clay		47.3	1.50	70.95
" bottom puddle		50	.60	30.00
" puddle applied		38	.75	28.50
" rock excavation		15	4.00	60.00
Square yards cement plastering		824	.40	329.60
" tar coating		1,018	.10	101.80
Feet of tile drain		714	.50	357.00
Extra work				140.00
				$26,134 02

Cubic yards of Roxbury stone measured in wall weighed 3,149 pounds.

Foreman	238 days, at $4.00		$ 952.00
Masons	657	4.00	2,628.00
Engineers	321	2.75	882.75
Laborers (white)	1,358	2.25	3,055.50
" Italians	3,072	1.50	4,608.00
Double teams	203	5 00	1,015.00
Single teams	136	3.00	408.00
Derrick	396	3.50	1,386.00
Portland cement	598 bbls, at	2.50	1,495.00
American cement	1,433	1.20	1,719.60
Stone			5,000.00
50 M Lumber		16.00	800.00
Sand and gravel			324.00
Brick			1,723.00
Grading			523.00
Teaming, derrick and incidentals			500.00
			$27,019.85

The reservoir has now been in use nearly one year. At an examination made last summer, when the water was drawn from it, everything was found in perfect condition. The reservoir appears to be a success in every particular.

The water drawn from it has been uniformly good, containing no trace of algae or fungi growth, and always of the same excellent quality which characterizes it at the pump well.

In closing the paper, I cannot help saying a word in favor of covered reservoirs for the storage of all waters obtained from underground sources, or waters which have been properly filtered.

This is the ideal way of supplying water to a city or town. A jug or bottle carefully cleaned, filled at a mountain spring and tightly corked could not give as good a water.

I hope that the number of covered reservoirs will increase in the near future, and that the people will insist that the same degree of neatness now required in the preparation of food shall extend to the water supply, and that they will not be contented to drink the water from surface supplies without filtration, in which frogs and numerous other animals and water plants, large and small, pass through all the phases of life, death and decay.

WATER SUPPLY OF WALTHAM.

BY

GEORGE E. WINSLOW, SUPERINTENDENT.

(Read December 13th, 1893.)

The receiving, or filter, basin of the Waltham Water Works, from which the City of Waltham obtains its present supply, was built in 1873. Its location is about 30 feet from the old shore line of the Charles river, and, on account of the surrounding land and river, is shaped similar to a steam indicator card, covering an area of about 10,000 square feet. One end of it was left open and riprapped, with the intention of extending it at some future time. The depth of this basin in the center was about 8½ feet below the average surface level of the water in the river; the bottom sloped upward from this point to the wall that surrounded it, at a grade of 1 foot rise to 3 feet run. It has no direct connection with the river, but was originally intended as a filter for any water that might find its way into it from the river. However, from subsequent experiments, it was found that there was very little water derived from that source, but most of the water obtained was that which was intercepted in its underground passage from the water shed to the river. During its construction, work was carried on both night and day, and continuous pumping was required, of between three to four million gallons in twenty-four hours.

From the north end of this basin, a stone conduit, about 56 feet long, 2 feet wide, and 3½ feet high, conducted the water into the pump well, which is built within the pumping station, of brick and stone, water tight, rectangular in shape, and 6½ feet wide, 20 feet long, 11½ feet deep. From this, the pump of one and one-half millions gallons capacity in twenty-four hours, originally obtained all the water that was used. In 1881 a second pump of the same capacity was put in, and the supply was found adequate to meet the requirements of the town at all times, until the summer of 1883, when it was severely tested by a drouth which continued through the summer and autumn. For sixteen consecutive days, when in a day's run of fourteen hours, there were pumped something over nine hundred thousand gallons, only one pump was available for the entire time, and it was even found necessary to run that at a reduced speed, during the last three or four hours of each day.

During 1886 it was fully demonstrated that the water supply must be increased, and the Water Board engaged T. Howard Barnes, Civil Engineer, to make surveys and plans for that purpose. Test pits and borings were made at a number of places, some as far distant as 1500 feet from the basin, which was the farthest that the slope of the surrounding land would allow. Several were placed along the shore of the river, and about 30 feet from it, which were used to ascertain the character of the soil and the depth to which it would be practicable to excavate. Levels, taken on the water found in

the pits, showed that the ground water fell with that in the basin, as the basin was pumped down, and that the difference in level was small. While the work was being done, the pumps were run for seven consecutive days, the basin pumped to the lowest point that the pumps would take water, and held at that point as nearly as possible. By these means it was found that the capacity of the basin was about 1,137,000 gallons in twenty-four hours, and, on account of the nature of the earth, it was found better not to extend the basin, as was originally intended, but it was recommended that the present basin be deepened.

In 1887 Mr. M. M. Tidd was called upon to visit our pumping station for consultation in relation to the proposed extension of our supply. By his suggestion a five inch pipe was driven, about 30 feet from our basin, and about 20 feet from the river, to a depth of 83 feet. While this work was being done, samples of earth were taken at different depths. His opinion was similar to that of Mr. Barnes', and he submitted a plan consisting of sixteen four-inch pipes driven to a strata of suitably coarse material, which the five-inch well had shown to be in abundance at 45 feet. The plan was to connect these four-inch pipes at the top, then with one, or both, of our pumps, and to use them to supply the city while excavating a well of suitable size, and, when found necessary, to pump from at other times. Nothing further was done in regard to an additional supply until 1891. At this time our Water Board, not being fully satisfied with the plans for an increased supply outlined by previous Boards, and realizing the difficulties and importance of an engineering undertaking of this character, hoping to get additional ideas, determined to employ another consulting engineer, and to lay before him, for review, the plans and reports already on file at their office, with a request that he make a minute, personal examination of the whole subject.

Mr. F. L. Fuller, of Boston, was chosen as a consulting engineer, and, after thoroughly examining the plans and reports of previous engineers and making a survey of the basin and surrounding grounds, he submitted a plan for deepening our basin. This plan was to build a well in the center of the basin, 40 feet in diameter, and from 15 to 20 feet deep, also to extend the suctions of our pumps to, and into, this well. This plan was adopted and the well was built during the summer. It was described by Mr. Fuller at one of our meetings last winter, and the description may be found in Volume VI, No. 4 of the Journal.

While the well was being built, the water pumped from it was gauged, both by the amount put into the reservoir and by weirs set so as to take all that was not used other ways. It is safe to say that our supply is increased from a minimum of 1,137,000 to fully 5,000,000 gallons in twenty-four hours, which is probably sufficient for the use of our city for a number of years to come. The building was accomplished at the expenditure of about $11,000, which includes the contract price, all charges for engineering, and other labor.

Our work to obtain a supply at the location being practically completed, it was thought best to protect it from the growth of algae, etc. Different ideas

and plans for this purpose were carefully considered, until this summer. At that time, Mr. F. P. Johnson, City Engineer, was called upon to perfect and make plans for covering the basin and well, which he did. These plans have been carried out, and we now have an abundant supply of excellent water, covered at its source, so as to exclude all light, and in a manner that is not in general use, but is perfectly satisfactory to our Water Board, and to all interested in work of this kind.

BASIN AND WELL COVERING OF THE WALTHAM WATER WORKS,

BY

F. P. JOHNSON, CITY ENGINEER.

(Read December 13, 1893.)

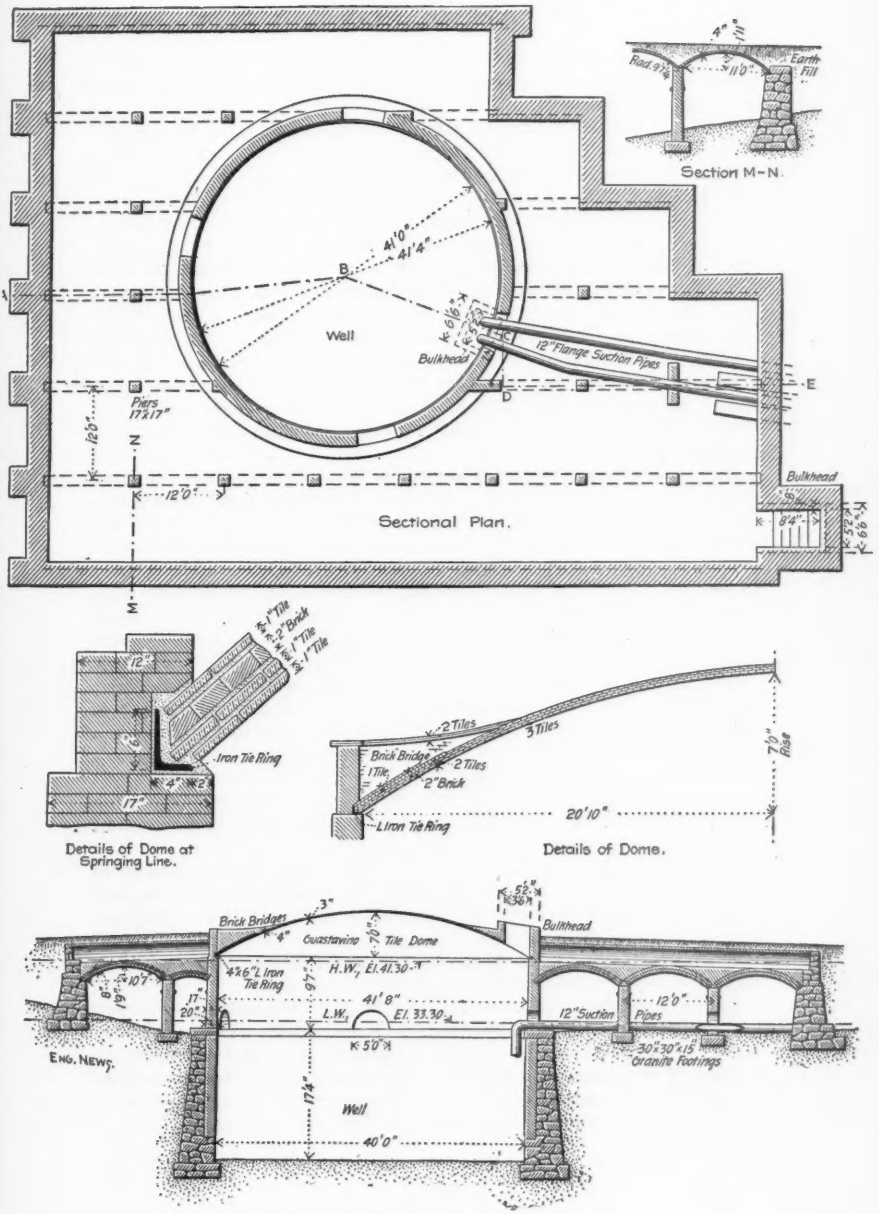
Mr. Winslow has spoken of the character of the ground at and immediately adjoining our pumping station. It may, perhaps, be in order to add just a word as to the peculiar situation of the well, by which its water shed is virtually enlarged, and which has perhaps much to do with the notable copiousness of its water supply.

What is known to geologists as the "Boston Basin," a gigantic sink hole or depression of the earth has its circumscribing fault (or seam in the rocks) passing just about under our well. The well being sunk in exceptionally loose drift material at the edge, so to speak, of the basin with ledge an unknown distance down while the ground changes in character a short distance to the north and west, ledge there being near the surface of a farm and wooded country of glacial drift not so much acted upon by moving waters.

Our conditions are somewhat exceptional.

Scarcely had I taken charge, last March, of the work of the City Engineering Department of Waltham when the Water Board requested me to prepare designs for covering the basin and well so as to exclude light, or for covering the well only and filling the basin and the board signified its desire to have the work completed by the first of June, if possible. Some three or four ready prepared designs were handed me, and each of the three members of the board privately gave me the outline of an idea which he would like to have developed. As requested, I prepared designs until some thirteen in all were considered. It is clear that the board had given the matter considerable thought, and it was therefore with some hesitation that I advised the design used and which was quite different from those previously considered.

The lowest price named in connection with the four plans first referred to called for an expenditure of $4,500.00 for covering the well alone, exclusive of walls, filling up the basin or other work, all of which items were to be done by the city.



Details of Dome at Springing Line.

Details of Dome.

Section A-B-C-D-E.

BASIN AND WELL—WALTHAM WATER WORKS.

We soon developed the probability that it would cost more to fill the basin with earth than to roof it over, to say nothing of the loss of storage which such filling would involve.

My estimate of cost of the plan carried out was $5,854, aside from earthwork or stone walls.

Omitting these items the work has cost $5,187.50.

Everything included up to date the cost has been $5,846.50.

The stone and earthwork were omitted from the estimate because it was not known how much of the stone retaining wall around the old basin would prove to be in such condition that it could be made use of. When we came to do the work we substantially rebuilt the whole. There is perhaps $300 worth of odds and ends of cleaning up and loam spreading yet to be done, and there is in contemplation some landscape gardening; but which is entirely distinct from any connection with the work here described.

All materials save the Guastavino stuff, to be spoken of later, were purchased and all work carried out under the direction of the Superintendent of Water Works, Geo. E. Winslow, and I feel that great credit is due him for his management.

The covering will, I think, be readily understood from the blue prints of the design and more fully illustrated by Mr. Winslow's progress photographs, taken by him from time to time as the work progressed. [Blue prints and photographs were distributed.]

The basin is covered by ten inches of loam, overlying coarse gravel from two to twenty-six inches in depth (according to location) filled upon covering arches of 4″ brickwork of 23″ rise and 11′ 6″ span, sprung between lintel arches of brickwork 17″ wide and 8″ deep, with 21″ rise and 10′ 7″ span, carried by 17″×17″ brick piers which foot on granite levelers 15″×30″×30″.

The well in the centre of the basin is covered with a material which has been somewhat extensively used for flooring in fire proof buildings; but, it is believed, never before made use of in this country for out of doors construction; although it would seem to be especially well adapted to such purposes as this, being nothing more than a 1″×6″×12″ fire clay, corrugated tile, laid in Portland cement. It is a patented article controlled by the "Guastavino Fire Proof Construction Co.," of New York and Boston, which concern put in this portion of our work.

The only material in any portion of our cover, other than stone, cement or baked clay, is a 4″×6½″ wrought iron, forty-five pounds to the yard, tie ring, entirely bedded in and covered with cement and set to receive the tile of this well cover where it foots upon the well wall.

The economy for us in the employment of this Guastavino construction was that by its use we were able to avoid expensive centering.

Owing to the nature of materials of which our cover is built, we believe that there will be scarcely any expense for annual repairs and no chance for contamination of the water or foothold for growths which shall befoul it.

Some of our methods of handling materials of construction, etc., might perhaps have an interest; but I will not trespass further on your time except to answer any questions you may wish to ask on points not made clear.

DISCUSSION.

MR. BRACKETT. I would like to ask Mr. Johnson if he can give us the cost of covering the well, separated from the cost of the entire work?

MR. JOHNSON. That was done by contract; it was the only work done by contract. We raised the walls of the well proper up to four inches below the spring line of the roofing. The contract price for the Guastavino roofing, from this point up, including the tiling, iron work and everything, was $1,916.42.

MR. FULLER. We have lately built a covered reservoir at Methuen, and it may be of interest, perhaps, if I give a few items of detail with regard to it. Instead of being a square reservoir like Mr. Forbes's, it is a circular one, very similar to the one which I described last year, which was built at Franklin. This is simply that reservoir with another ring of covering arches put on, of a larger diameter. This reservoir has a diameter of about ninety feet and holds about 1,000,000 gallons. All the excavation was done by day labor. The masonry wall was let out by contract at a $1.50 per perch for the laying. The stone was all taken from a neighboring locality, and paid for at the rate of $1.25 a perch.

The cost of this reservoir will certainly be less than $16,000; we cannot tell exactly yet because all the bills are not in and the work is not entirely finished. There was somewhere about 6,000 yards of excavation and about 1,200 yards of rubble masonry at $1 50 per yard. About 175,000 of bricks which cost on the ground $8.30, and the laying was $6.25. The cement cost about $2,400; the sand delivered on the ground, about $500; the crushed stone for the concrete in the bottom about $128; a road leading up to the reservoir about $112; the lumber for centering about $400; and the carpentry work in putting up this centering about $100. The method adopted for putting on the roof was perhaps a little different from the ordinary method. The centering was all put up before any of the brick covering was laid. The roof is eight inches in thickness, and the whole brick roof was put on in about six days. The whole reservoir was built inside of ninety working days. It cost about $16 to every 1,000 gallons of capacity.

The inlet and outlet pipe is fourteen inches, and comes in through the bottom, an extra thickness of masonry being provided at that point. The overflow pipe is a T put into the horizontal pipe and extending to the top. I expect we shall have an indicator to show the height of the water, so that there will be but little danger of overflowing.

MR. NOYES. I understand the Brookline reservoir has been emptied after having been in service for some months. Do I understand from your description, Mr. Forbes, that the piers in the reservoir were brick, that is a brick surface?

MR. FORBES. They were.

MR. NOYES. How did you find the surface of those brick piers as compared with the concrete surface, if there was any difference? Was there any growth at all on them or indication of anything different from the concrete surface?

MR. FORBES. I didn't see any difference at all.

MR. NOYES. I might say that it has been something of a question, and one of a good deal of interest to me, whether there would not be a growth of some sort on the brickwork in a covered reservoir which would not be on the concrete. We haven't had occasion or opportunity to examine the inside of the Newton reservoir since it was built, so I cannot say what condition the inside is in; but we have no reason to believe but what it is as good as when built.

This whole subject has been one of a good deal of interest to me from an engineering point of view, and we have before us to-day extreme types of covered reservoirs. We have the reservoir which has been described by Mr. Forbes, with piers twenty-four inches square and some nineteen feet high; then the Newton reservoir, which has been referred to, where the piers are twenty inches square and some fifteen feet high; and in their details they are very similar to each other, it may be the arches have a slightly larger rise in one case than the other. But we have the extreme case before us as presented by Mr. Fuller in the covered reservoir at Methuen, which is somewhat similar in design to the Franklin reservoir, as I remember it, and the piers nineteen feet high and twelve inches square. And we have the case brought before us to-day by Mr. Johnson, which is exceedingly interesting, of arches of four inches springing from piers seventeen inches square.

The point of extreme interest in Mr. Johnson's work is the use of the tile arch, the extreme thinness of the arch, which is some forty feet in diameter, the fact that the arch covering the portion of the filter basin outside of the wall is four inches thick, with no solid spandrel filling, and without apparently earth filling; and, apparently, twelve inches of earth over the top of the four inch arch. On first looking at the plan it struck me as an extreme case of light work, and I should like very much if Mr. Johnson could give us a little more information as to the practical results, that is so far as stability goes as indicated up to the present time. It becomes us as engineers to design our work with sufficient stability to do the work required, and at the same time to save as far as possible the expense which may be wasted in making work of unnecessary dimensions. And if the designs as carried out by Mr. Johnson and Mr. Fuller show sufficient stability in a length of time, it shows us what we can do with good work, and how much we really can save for our clients. Of course it is an exceedingly delicate matter for an engineer to adopt these extreme conditions if he hasn't precedents of successful work to draw his conclusions from.

MR. JOHNSON. If Mr. Forbes will kindly answer one question before I answer Mr. Noyes, I think it will bring out very clearly the underlying distinction between the two pieces of work. I would like to ask Mr. Forbes about how much cement he mixed at a time, and how many persons there were using from a mixture at the same time?

MR. FORBES. We mixed half a barrel at a time.

MR. JOHNSON. Wet the half barrel at once?

MR. FORBES. Yes. We had four masons working in one gang, and it would last generally from fifteen to twenty minutes.

MR. JOHNSON. What were the proportions?

MR. FORBES. Two of sand to one of American cement, in laying the foundation walls.

MR. JOHNSON. That brings out the point I wish to emphasize, not as justifying or otherwise any work we have done, but as bringing out the underlying ideas in the two methods of construction, and the distinct intentions in making the work. I have no question as to the stability of any part of the work, not excepting the four inch covering arches, and there I deliberately omitted any filling in the spandrels between the arches, that is any filling by cement or concrete, though it is filled with gravel. And I did it with a view to economy, and also in consideration of the conditions under which we worked. Our work is a filter basin not a storage reservoir. We have a bank of material against it which has been in place a long while. The heaviest weight which we think can ever come upon it will be a crowd which may gather to view a boat race on the river. Now, in designing the work it presented itself to me whether to put the additional expense which would be required into concrete backing in the spandrels, in the valleys, or omit it, and I took the alternative of omitting it for the sake of saving expense, believing that we had ample strength. But I paid particular attention to mixing the cement, to the cement and the way it was treated. While the work was in progress I personally watched the mortar beds more than anything else. I insisted on careful selection of the sand and on all materials being mixed very dry, indeed during a portion of the work we heated our sand for the purpose of getting it dry. Then the cement was wet pailful by pailful, although there were from six masons upwards at work all the time, and I suppose the cement wasn't wet two minutes before it was in place in the work. The brick before being used were soaked in water and then allowed to drain for something like twenty minutes; and the amount of water was carefully gauged in mixing the cement. I think the brick certainly did not rob the cement of any water, and that the initial set of the cement would be a permanent set.

Something like three weeks after the work was completed, we tested it by having four men haul a 425-pound stone roller, with a tread of something like 20 inches over the well, and by examining the amount of bearing I estimated that that test was equivalent to a dead weight of about 1,700 pounds per square foot, under the conditions under which we applied it. By accident the roller at one place dropped about five or six inches on to the covering of the well without any disasterous result. Of course that applied a very much more severe test at that particular spot, and it certainly was not any stronger place than anywhere else. I felt therefore quite well satisfied with the work so far as we could test it then.

MR. NOYES. Was this work laid in American or Portland cement?

MR. JOHNSON. American Rosendale cement was used.

MR. NOYES. Altogether?

MR. JOHNSON. Altogether, excepting in the work of the Guastavino Construction Company. They used Portland cement without the special pains we took in the handling of the American cement. But I really believe we got superior results with our American cement to what they got with the

Portland cement which they used in the work. Their work is amply strong, I do not cast any aspersion on that, but our American Rosendale cement really gives us a stronger cement than they got with the Portland, and the reason is, I believe, the difference in the way in which it was used.

MR. NOYES. What brands of cement did you use?

MR. JOHNSON. We used Connolly & Schaefer and Hoffman; the greater portion of the cement used was the Hoffman cement.

MR. NOYES. Did you use any different method in mixing your Portland and American cements, Mr. Forbes?

MR. FORBES. I did not. The Portland cement was used on the brickwork only, and mixed in much smaller quantities.

MR. NOYES. Was American cement used on the brickwork in the arches?

MR. FORBES. No; all the brickwork in the arches were laid with Portland cement mixed in very small quantities, a pailful or so at a time.

MR. NOYES. That is, you would use greater care in mixing the Portland than the American?

MR. FORBES. We did, but at this time of the year it had got rather cold; and of course cement mixed in the winter time, with the thermometer about forty, will set very much slower than in the summer time when the thermometer is seventy or eighty.

MR. NOYES. I should like to ask Mr. Fuller whether he used American or Portland cement?

MR. FULLER. We used, I think, a mixture in the piers of American cement and Portland cement, but in the covering arches and in the stone work, and in the rubble masonry wall, the cement was entirely American cement. At Franklin we used Portland cement entirely in the piers.

MR. NOYES. Was that on account of the design?

MR. FULLER. No, we thought it would set quicker and that the piers would be less liable to swaying and distorting by getting out of plumb. By staying them we had very little trouble, and I don't think after the lintel arches were on there was ever any movement of the piers at all.

MR. FITZGERALD. I think there is one point in connection with these covered reservoirs that has not been fully dwelt upon, and that is the head of the water on the outside. When the reservoir is full and kept full for some time, the head of water outside must be about the same as on the interior, and as there are violent and sudden fluctuations in the level, when the water is drawn down, I would like to ask Mr. Forbes and Mr. Fuller if they have made any investigations on the question of the strength of the bottom to resist the upward pressure, if that has entered into their calculations? I notice that in both of these reservoirs there is no invert, and a very thin floor composed of clay and a thin lining of concrete.

MR. FORBES. I remarked in my paper that when the bottom of the reservoir was built on material where the water was liable to get under the concrete, you might make the bottom like the top; that is you could spring arches from the piers, thus forming a bottom that could not be forced up under any circumstances, without forcing the whole roof up. Our reservoir

we built in an excavation in one of these clay hills like Parker Hill. When we first filled the reservoir we let it stand nearly full for, I think, ten days, and then we drew it off, and it was empty for a week or ten days, and I didn't see any indication of the water forcing the concrete up on the bottom. In fact the whole reservoir was practically tight; there was no water coming in anywhere. This summer, after the reservoir had been in use several months, we drew it off again, and we examined the bottom and sides carefully, and there was no indication of water entering through the walls or forcing itself up through the bottom. That is one reason why I say the walls of a covered reservoir should be very thick and very carefully made, because if there are spaces in the wall, when the water suddenly falls the flow through this wall might wash some of the clay, perhaps, back of it, and if it once began to wash the hole would gradually get larger and larger, and it would be only a question of time when the whole would tumble down. And having this in mind was one reason why I adopted a very heavy construction of the side walls, so as to guard against the water which may rise on the outside of the walls, perhaps, nearly as high as the overflow line, and then, when the water in the reservoir is suddenly drawn down and it is nearly empty, as our reservoir fluctuates from five to thirteen and fifteen feet every twenty-four hours, if there were pits in the bottom of the wall, or if there were pits back of the wall, or if there was any chance for the water back of the wall or in the wall or behind the wall to get underneath the concrete in the bottom and pass through, then it would only be a question of time when it tumbled down. That is one reason why we poured down barrel after barrel of cement and formed a grout around the stones, so as to be sure there couldn't be any holes or any chance for this water to run back and forth through the wall. I think that ought to be guarded against, or sooner or later it may all come down.

MR. FULLER. I would say with regard to the Franklin and Methuen reservoirs, they were both built in material which was very hard, compact and homeogeneous, and I think it would be very unlikely the material would hold much water anyway. The filling behind the walls in both cases was thoroughly rammed and a great deal of time and labor was spent in both cases in making the backing thoroughly hard and compact, I don't see how it can pass much water. The Franklin reservoir was drawn off after it had been in use about a year and a half and carefully examined, and so far as I know there was no indication whatever of any rise on the bottom. The Methuen reservoir has not yet been filled, but I apprehend no trouble on that ground, and I see no reason why there should be.

MR. COFFIN. We have had an experience with the reservoir at Cohasset. It was covered with cement concrete six inches thick, with one inch of plaster on top; this covered the bottom, went up the sides and into the bank under the core wall. The water was drawn down suddenly one day, and the superintendent saw the bottom beginning to rise. He went into the gate house and got an ax and went down and cut a hole in it, and the water gushed up and the bottom went down. The reservoir was built in material which

seemed to be almost absolutely impervious to water, but in drawing it down so suddenly I suppose there was a pressure upwards on the large surface on the bottom. I presume it is different in these covered reservoirs, where the bottom is divided up into small squares by the piers; I don't know just the construction of those piers but they probably have some effect at least in shortening the span and holding the bottom down. I mention this as one instance where the bottom of the reservoir came up from the pressure of the water.

MR. FITZGERALD. There is one other matter I want to refer to. I am not quite sure as I heard distinctly, but I thought I heard one member say his experience in some of his work had led him to believe that the American cement had given better results even than the Portland, and he mentioned certain brands. As this is so entirely contrary to all engineering experience, I hope further details will be given to us, so we may become thoroughly acquainted with the foundation for this experience as it certainly ought to be of a great deal of value if founded on absolute experiment and fact.

This large well at Waltham is an extremely interesting one. I have for some years taken an interest in these large wells, and from time to time have seen them in process of construction; and particularly in the west they use a great many of them, both for public water supply and for furnishing railways with water to fill their locomotives. Nothing has been said here today about the method of sinking these wells. I have seen wells from twenty to forty feet in diameter, sunk from thirty to forty feet in depth, and varying in cost from $20,000 to $2,000, depending upon the method of putting them down, and the amount of care and thought expended in that direction. One of the largest wells I know of, and one of the most remarkable, and one of the first ever built in this country, is in Prospect Park, Brooklyn. That is a brick well fifty feet in diameter, and sunk to a depth of sixty feet. It was built on a curb and sunk that depth by excavating very carefully in the interior; and that is the method generally employed, where economical construction is provided for, I think. Of course there are places where, perhaps, it is not possible to do it. I thought it might be of interest to call the attention of members to this matter of sinking. If any of you are going to put down large wells, that is one of the most important things to study in the beginning.

MR. JOHNSON. I think Mr. FitzGerald has reference to me in speaking of Portland and American cement. I perhaps did not make myself clear. I did not wish to be understood as making any statement that American cement, used under the same conditions, is superior to Portland cement. What I did intend to say was this, that the Company using the Portland cement in this case, mixed their cement and wet it some little time before it went into their work; and while nominally mixed two to one, I think really it was a good deal nearer three and a half to one. They did not measure the materials as they went in, as we did. Our cement was used with brick which were very damp, and yet not running in water, and before the cement had been wet more than five minutes at the outside, it was in place on the brickwork. The

Portland cement had been wet for some little time in many instances before it was used in the work, and their tiles were used entirely dry. I permitted the work to go in in that way because of the guarantee they gave us that the work should be submitted to a test which we approved, which it amply stood, and further, because I believe that ample strength was had by that use of the cement. Perhaps that answers Mr. FitzGerald's question.

MR. WALKER. We do all our business at Manchester open and above board. The reservoirs are all open and the saloons are all open. (Laughter.) We are about to build a reservoir in a solid ledge, and I want to ask if any engineer who can tell me how to make it tight. I understand there is some difficulty in getting a tight reservoir in rock where there are seams

MR. TIDD. Mr. Walker seems very anxious to know how to fill up the cracks in a ledge, and to be afraid that his reservoir won't be tight. I should say with the saloons all open it might get tight. (Laughter.) A reservoir in solid ledge is rather expensive, perhaps, but my idea of an ideal reservoir is one which would be solid masonry, and if the masonry is properly put in, it can be made tight. I suppose a reservoir in any ledge, and I never saw a ledge that wasn't seamy, can be made tight with proper lining. The lining probably would have to be cement or clay, and cement would be better. A friend of ours built one in Woburn in a ledge, and he had some difficulty in making it tight, but he afterwards accomplished it by lining it with clay. When they first commenced to pump into it, they got it about half full and they couldn't get the water any higher ; so they drew it down and lined it inside with clay and it has been all right ever since, about twenty years. I don't think Mr. Walker will have any difficulty if he goes to work in the proper manner.

MR. WALKER. How thick should the lining be on the bottom ?

MR. TIDD. They didn't put any on the bottom, but on the sides they put six inches of clay.

THE CONSTRUCTION OF RESERVOIR EMBANKMENTS,

BY

LUCIAN A. TAYLOR, Civil Engineer, Boston, Mass.

[Read Jan. 10th, 1894.]

The construction of Reservoir Embankments, the subject of discussion to-day, is one of great interest and importance to engineers, water-works officials, and the public generally.

The pressure exerted against an embankment holding, we will say, forty feet of water, is something enormous, being more than twenty-five tons for each lineal foot of embankment. To resist this pressure under all the varying conditions of weather, the rapid rising of the surface of the water in the early spring, at a time when the embankment or the exposed portion of it is in its weakest condition through the action of the frost, requires good material and plenty of it.

An earthen embankment, whatever the material, clay, loam, sand or gravel, will be penetrated by the water in the reservoir to ascertain depth, depending on the depth of the water and the nature of the material used.

It would be very interesting to know to what depth this penetration extends under different circumstances and with different materials in the embankment.

The effect of the resistance of earth in an embankment, is to retard the flow, and the pressure is exhausted. The water is fatigued and loses its force. In the case of fine material mixed with clay or even fine sand, when the particles are small, the penetration of embankments, the writer believes is not very great.

Every fine particle of material occupying a space between coarser particles has its effect in the resistance it offers to the flow of water.

As each location, each embankment, and piece of work to be done, has its different local conditions, no set rule or formula can be made to determine the minimum safe thickness of an embankment. Each individual case should be referred to a practical and experienced engineer.

Practically, the writer believes it is much easier to build a water tight embankment, than a water-tight masonry or cement concrete wall, each having a thickness as ordinarily designed for reservoir dams.

The writer does not now call to mind any instance of an embankment being carried away by percolation through the body of the embankment.

Almost invariably, the leaks and breaks take place along the line of connection with the original ground or foundation, or in contact with stone or concrete masonry, or cast iron pipes, all substances with which it is difficult or impossible to make a bond or connection with an earthen embankment.

Most earths in their natural position are to a certain extent porous, or have viens, and fissures and water ways through them.

It is also true that most earths may be made into a water-tight embankment many times by the simple rehandling of the material.

The shrinkage and consequently the increased compactness of all earths, as we ordinarily find them, is largely, if not wholly, due to the closer and more perfect mixing of the fine and coarse particles of earth.

We have a good example of an earth embankment in the reconstruction of the dam on Lynde Brook in Leicester, a storage basin of the Worcester Water Works.

In the spring of 1876, a break was made in this dam about 200 feet in length, the result being, the emptying of the reservoir of about 660,000,000 gallons of water, and a large amount of damage to property in the valley below.

It is not the province of this paper to discuss the causes of the break, but simply to give a brief description of the manner of building the embankment, it is well to say, however, that it was no fault of the material or construction of the embankment.

The sections show an embankment fifty-five feet wide on top, it having been the intention to raise the dam five feet at some future time. The up stream slopes are two horizontal to one vertical, and down stream about two and one fourth to one. The essential feature of the new work was the building of an earthen embankment, through which was a clay puddle wall.

The greatest depth of water in front of the dam is about forty feet. The top of the dam is about four feet above the wasteway, and the embankment 59′ 3″ in the highest place.

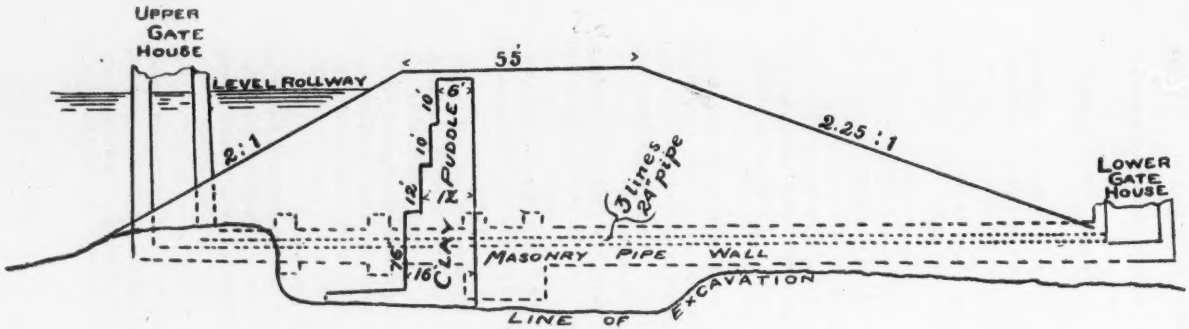
Down stream from the top line of the lower slope no pains were taken as to the quality of the material except that it was not perishable. Stones, bricks and much coarse, washed material were placed in the lower slope.

The clay puddle wall, the up-stream face of which is on a line with the top of the inner slope, was built in the following manner: The selected material was put on in layers six inches in thickness. The large lumps were previously broken, and stones of more than two inches diameter were thrown out. After each layer was in place it was cut with twelve inch garden spades in cuts not exceeding one inch in width. It was then cross-cut in the same manner.

The thickness of each layer after spading was about four and one half inches. This process of spading cut and cross-cut each layer twice.

Where the clay puddle came in contact with the natural ground in the lowest parts of the foundation, and where the greatest care was exercised, pea gravel was mixed with the clay, from fifteen to twenty-five per cent. of gravel being added. The size of the gravel used was from one fourth to three fourths of an inch in diameter.

At the time the breach was made in the dam, a pit was excavated in the natural ground from fifteen to thirty feet in depth, sixty-three feet in width, and one hundred feet in length, or cross-section of the dam, that was cleared of debris in the reconstruction.



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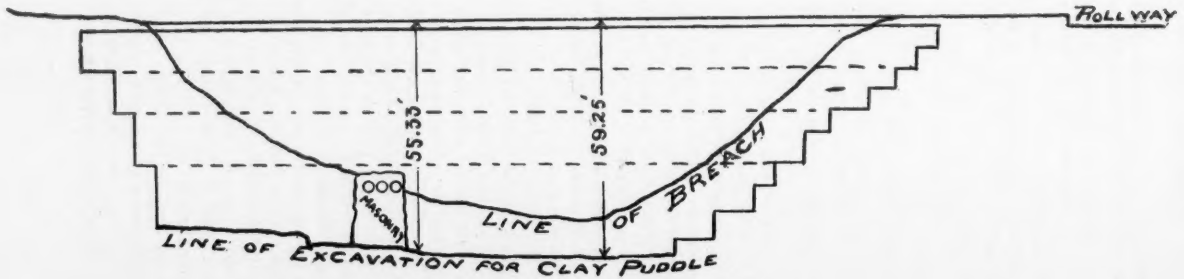


LONGITUDINAL SECTION.

LYNDE BROOK BESERVOIR DAM, WORCESTER WATER WORKS.

The bottom of this pit was from twelve to fifteen feet below the bottom of the reservoir in the deepest place, and from fourteen to seventeen feet below the bottom of the supply and waste pipes, which were laid in a masonry wall imbedded in the natural ground on one side of the pit.

In this pit the width of the clay puddle wall was from thirty to forty feet on the bottom, or in contact with the natural ground. It also enveloped the pipe, and cut off walls of which there were six, on sides, ends and one foot above the top.

At this elevation, or thirty-five feet below the top of the embankment, and thirty-one feet below the crest of the wasteway, the wall was made a uniform thickness of twelve feet. The thickness of the wall below this elevation, except at the points mentioned, was sixteen feet.

The clay puddle was carried to a point two feet below the top of the dam, at which elevation it was eight feet in thickness.

The difference in thickness of the wall was made by horizontal steps, on the up stream side of the wall, also all excavations, steppings, and toothings, into the natural soil and the embankment of the dam, were made by horizontal and vertical excavations or steps.

The embankment on the up stream side of the puddle wall and also that on the down stream side to the top line of the lower slope, was built of excellent material, put on in from four to six inch layers, rolled with a heavy roller, and at the ends and other points not accessible to a roller, thoroughly rammed.

The material for the embankment was, in fact, only slightly inferior to that used in the puddle wall. With the exception of the points mentioned, the puddle was used in its natural mixture and probably contained about one-third pure clay.

During construction, the embankment was kept at least six inches higher than the puddle wall.

Great care was used to get rid of any pools of water or excess of moisture by dipping it up in buckets, and also by exposure to sun and air before working upon it again.

This embankment has now been built seventeen years, and there is not the slightest indication of any percolation through it. Indeed it is the belief of the writer, that it is doubtful if the percolation from the reservoir even reaches the puddle wall.

It is a somewhat unusual condition to build an embankment sixty feet in height and less than 200 feet in length. It is believed, however, this was accomplished with practically no settlement in the embankment, and consequently no breaking of the material at the points of contact with the original ground and old embankment.

Whether it is wise or economical to build a dam of earth entirely, must depend upon the circumstances or the kind and amount of materials at hand, and the ease with which they can be procured. There is, however, no doubt that perfectly water-tight embankments can be built, and of ordinary material, perhaps the most important essential being a firm water tight foundation.

DISCUSSION.

MR. DARLING. I would like to ask Mr. Taylor whether he would recommend building a dam out of earth, with no center core?

MR. TAYLOR. It would depend entirely on the circumstances. It would be a question of expense and the kind of material you found.

MR. DARLING. That may be right, perhaps, in places where they don't have animals that bore through dams. But in the case of the dam which was built at Leedsville, it was said at the time it gave way it was a musk-rat that bored through. Now, wouldn't that be likely to occur in the same way with any dam, if there wasn't a center core?

MR. TAYLOR. I don't believe it would be possible for any animal we have in this country to bore through the dam I have described, or one like it. I have never known an instance of that kind. There is a reservoir of 160 acres, and it is out in the country, I don't know whether there are any musk-rats there, but I don't think it will make any difference whether there are or not, and it has been in that condition seventeen years, and is just as good a piece of work as can be found in England. In this particular case, the embankment is excessively heavy, but I don't think there is the slightest danger from musk-rats in material of that kind.

THE PRESIDENT. We would like to hear from Mr. Freeman.

MR. FREEMAN. Mr. President, I did not come here expecting to speak, but rather to listen and learn. However, continuing in the line of the suggestion of Mr. Darling, which Mr. Taylor has just answered, I would like to allude to an experience, of which Mr. Tidd can tell us something, where another kind of an animal tried to ruin Mr. Tidd's reputation. This was not a musk-rat, but was a woodchuck, and before his operations were discovered, he had dug his hole 12 or 15 feet into a reservoir embankment which had been built in a very thorough and compact manner.

It seems to me that a core wall is always a good thing, and that in almost any ordinary case it is worth its cost. There are cases, of course, where its cost would be prohibitive, and there are cases where the material is of such an excellent nature that one is justified in getting along without it. But I will confess myself to having a very strong preferance for a core wall, both as a preventive against the working of musk-rats and of woodchucks, and as a means of making the embankment tight; and also as a means of causing the destruction of the embankment to take place gradually in case the water does penetrate it.

As to one other statement of Mr. Taylor, that regarding the relative tightness which could be secured with a core wall or with an embankment without a core wall, it seems to me that depends entirely on the material used. In many cases where you have what here in New England we call "pudding gravel," you can unquestionably make the bank most admirably tight with that alone. But, on the other hand, if you have a loose sand, as in one case with which I have had some experience recently, where there is no gravel that will puddle, and no clay within a radius of several miles from the point where

it is desired to build a dam that may ultimately be some 40 feet high, nothing but pure, loose sand ; in a case like that it would be almost impossible to construct your bank out of that kind of earth so that it would be anything more than a gigantic filter when you got through, unless you put something else in to make it tight, or brought material at great expense from a distance for a puddled core or lining.

Now, you can unquestionably build a bank of pure, loose sand and get that bank into a very tight condition in the course of time, when the stream carries any considerable quantity of sediment. There is along the manufacturing canal at Nashua, a high bank composed of nothing but pure, loose sand, not a particle of clay in it, or within several miles of it, and this manufacturing canal has been standing there now for the past 60 years. Skirting the bluff, the canal 9 feet deep, the water level 20 to 30 feet above the outer toe of the embankment, built wholly in pure sand through which water naturally percolates freely. The canal was small in the early days, and has been gradually enlarged, and though undoubtedly a great deal of water was lost by percolation at first, the canal has in the course of time become satisfactorily tight.

We may have that kind of a bank on a running stream, or on a stream that carries a moderate quantity of suspended matter. But, on the other hand, if you were to build an embankment for a reservoir which would practically store the whole annual flow of the stream, the water thus being infrequently renewed, or if you built such a bank where the water was very pure and the amount of clogging material in the water was very small, you might have to wait a very great length of time before you could get a bank built of pure sand into a perfectly tight condition.

I have had some experience in building banks of very pure sand, and in noticing how they could silt up afterwards ; and it simply amounts to building a bank that is not much better than a filter in the first place, and then waiting for this filter to become clogged.

One point, I think, to which sufficient attention has sometimes not been given, when trying to get perfectly water-tight core walls, is that stones have been used of rather too large a bulk. I think that in France, it is generally recognized that for the best work in the shape of a water-tight masonry wall, no stone should be used larger than one or two men can lift ; the same statement has been made by some of the best engineers in this country, that is, on a wall of that kind you can get much tighter work by hand work than by derrick work. I did not come expecting to speak on this subject.

Mr. Tidd. Mr. Chairman, I can say, as Mr. Freeman said, that I came here to get information from others rather than to say anything myself. But speaking of reservoirs, on general principles I should say an ideal reservoir, according to my ideas, would be one of solid masonry. There is one thing sure about that ; it never can wash away. But, of course, wherever we build reservoirs we have to be governed largely by the material which is at hand to make them. I have built them of solid earth, without any core wall at all, where I could'nt get the material very easily to make a core wall of, and so

far they have been a success. But the earth was good enough to make a puddled wall of all of it, so in fact it was really a puddled wall. Mr. Freeman has alluded to one case, where I had good material to build in. It was in Maine, in Lewiston, where we had as good material as could be had anywhere, a sort of clean gravel mixed with clay which was in fact nearly as hard as stone, and in that case I used a brick priming wall. The embankment was 15 feet wide on top, the inside slope was one on one and a half, the outside one on two, and two years after the work was built we found a hole there made by an animal that we supposed was a woodchuck. He bored a hole in so far that we could run a pole in 16 feet. That was as solid earth as ever I saw put in a wall, and as solid as we could ever put down in a puddled wall, and it seems an animal did bore into that. But of course he could never have got through the brickwork ; that would stop anything.

As I said before, my idea of an ideal reservoir would be one of solid masonry, and it can be made tight, and when it is once made tight it is there forever. But we can't always afford to build a reservoir of solid masonry, and the next thing to it is to have a core wall of masonry, which I should construct every time when I could get the material. I had occasion to build a reservoir once in Prince Edward Island where all the stone on the island is the poorest, softest kind of red sandstone in layers, drift rock all through, fissures between the layers, and all the stone we could get to use even for the rip-rap on the inside of the reservoir we had to bring by vessel twenty-four miles across the Northumberland Straits. So of course in that case we could not very well afford to build a masonry reservoir. So I endeavored to make it of a puddle of clay which they had there, which was so poor that it broke through many times into the fissures of the rocks and away down the hill. But after a long time, by using cement and concrete in those places where it could be done, we succeeded in getting it tight. To give you an idea of the material used, I will say that near the reservoir, 50 or 60 feet below it, was a quarry where a man got out sandstone. Of course they used it as stone, for it was the only kind of stone they had there, and they used it in buildings. He complained that the water from our reservoir filled his quarry, and he brought suit against the city for damages. While the case was pending, or rather before he brought the suit, immediately before he brought it, while he was complaining to the authorities, I sent a man down into the quarry and he drilled a 2-inch hole down 10 feet, and that let the water all off straight down through the bottom of the quarry, very much to the owner's chagrin. (Laughter.) I merely mention that to illustrate the character of the material there.

There is one thing I have always studiously avoided in the construction of a reservoir, and that is the putting of anything like a pipe through the embankment. Of course we are obliged to lay a supply pipe in through the embankment, and in all those cases no matter what the material is, I have made it an invariable rule to lay a core wall across the pipe; even if don't go clear around the reservoir, I lay it far enough to make it sure nothing will get along the pipe; and the pipe which goes through the wall always has a

collar or flange cast around it, two or three inches high and perhaps two inches wide, and that I take very particular pains to bed solid in cement. When that is done thoroughly there is no danger of the water following the pipe. I have had occasion in the construction of dry docks to build coffer-dams, some quite large ones, where we were obliged to run timber braces through the filling of the dam. In all those cases I have taken pains to nail a cleat around the timbers so that there should be no passage along the timbers for the water to follow. Water is very insinuating in its pressure. It is not only the pressure, which Mr. Taylor has referred to, it is all that he speaks of, but it has also a tendency to bore small holes. It is insinuating, and if there is a crack ever so small, it will find its way through it and enlarge it, if it once finds its escape on the other side. I remember building a reservoir once in Nova Scotia, on a hill, where we had very nice clay indeed, and there we built a puddle wall, and puddled the bottom of it. Stone was too expensive to use there, and we built a carefully puddled wall entirely around the reservoir. It was on a side hill so steep that the bottom of the reservoir at the lower corner was higher than the natural surface of the ground, and we had to build quite a berme on the outside to support that corner. After the reservoir had been built and we attempted to fill it, we found a stream, which might have been an inch or an inch and a half in diameter, made its appearance at the lower corner, much to the terror of the contractor. He immediately wanted the water drawn out of the reservoir, which was then about half full. I insisted upon its being left as it was, and berated him for leaving some place in the wall without having been properly puddled. He claimed he had done it all properly, but I claimed the stream was sufficient evidence he had not. We kept the reservoir half full, (it was one we pumped into,) I think, for four days, and at the end of that time the leak stopped itself. It was simply a place where there were some lumps of clay which he had not properly puddled, and the water in its passage through it had finally dissolved the clay and had filled the spaces; and the reservoir stands there today, I think it has been there some seven or eight years, perhaps ten years, and is absolutely tight. It was simply that it wanted more thorough puddling. I have no doubt there are many gentlemen here who have had experience which would be interesting in that direction.

I remember a case in a dry-dock where the water blew up from underneath, and came up in a stream 6 or 8 inches in diameter. Of course that was something which was very hard to handle, but we did finally stop it by piling it with round piling, 20 or 30 feet deep, and capping it across the top with two layers of 12×12 hard pine, bolted down to the piles. That stopped the water coming up there, though it may be it forced it out somewhere else, but anyhow, it didn't trouble us afterwards.

But I suppose one of the worst spots in a reservoir is the discharge pipe out through it, or the inlet pipe, unless the work is most thoroughly done. I was connected with some works in Wisconsin one time where we built a reservoir that was filled by an artesian well which had on it something like 40 feet head, and from the reservoir we pumped the water to a standpipe. In

that case, of course, there had to be an overflow, and we built the overflow down through the bottom of the screen well. The bottom of the well was put in in solid concrete, and the pipe was made with a flange on it, as I have said I always do. It was set vertically and the top of the pipe was cut off at about 4 to 6 inches below the full level of the reservoir, and went down vertically, passed under the bottom and out into the river which was near by. The water, when it rose to the top of the pipe, went down vertically through the pipe. There was no path there for water to find its way through the sides, certainly, and we never had any trouble from it. That reservoir has been built about five years, and it is tight today, and in good shape. As I said before, Mr. Chairman, so I will say again in closing, give me masonry every time; and if I can't have the whole reservoir of masonry, I will have at least a masonry wall around the entire artificial embankment, and far enough into the natural earth to absolutely secure it.

THE PRESIDENT. We should like to hear from Mr. Noyes of Newton.

MR. NOYES. Mr. President, I do not know as I can add very much of practical interest to what has already been said, unless it be to refer to a description recently given me, of work successfully executed by an engineer, who had in his practice been obliged to adopt plans and methods for accomplishing desired results at the least possible cost. I was specially interested in the results he claimed to have obtained.

He stated he had built reservoir dams or embankments 16 or 18 feet high with fine sand, such as is found in the sand dunes so common on Cape Cod.

He described a reservoir embankment about 16 feet high, he had built with slopes one and one-half to one. The material in the embankment was fine sand and the slopes were covered with the turf taken from the ground. There was no appreciable infiltration or leakage of water through the embankment, and the reservoir was used for a number of years for storing water. A section of the embankment was ultimately carried away, the break being caused by the flow of water through a hole made by a woodchuck. He repaired the break by filling the hole or section carried away, with the material washed away or material like it and then facing the inside slope with a clay gravel, commonly known as hard pan, put on in thin layers with a total thickness of two feet. All stone above two inches in diameter were carefully picked out and the layers compacted by spading rather than by rolling or tamping. This facing was covered with four inches of broken stone and a layer of broken stone rip-rap 12 to 14 inches thick. He did not think it possible for any animal to bore through the covering. Water had been stored in the reservoir since the repairs were made and the embankments showed no weakness or leakage through them.

He is now engaged in building an embankment about 16 feet high and 2,000 feet long, the plans and details for and materials used in the construction of the embankment are similar to those adopted and used in the embankment just described. He found a more compact embankment could be made if the material used was not wet but slightly damp, and no water used while rolling the layers as put on. He had examined, by cutting through the embankment

constructed without the use of water, and found the material more solid or compact than the material in embankments upon which water was freely used. This opinion coincides with statements made in a discussion upon this subject, heard at a recent meeting of the Boston Society of Civil Engineers, and with some of the suggestions made here today. From his experience in building reservoir embankments he preferred a fine sand to other material.

While my experience in constructing, and observations made of reservoir embankments constructed by others, lead me to somewhat different conclusions as to the best material to use, the engineer I refer to is to a certain extent right, that is, the material should be perfectly compact, have no voids, will not expand or swell if wet or contract if dry, and will not be readily taken up if water gets access to it and be readily washed away.

By the use of a fine sand all of the conditions except the last are met and the efficiency of an embankment constructed with this class of material depends upon the measures adopted to keep water from acting directly upon it. One of the greatest difficulties met with in the discussion of questions involving the use of terms describing the various forms of glacial drift, surface or sub-soil loams or moulds or even stone is from a lack of uniformity of nomenclature used in different parts of the country or even among our own members.

MR. BRACKETT. Mr. Chairman, it hardly seems to me that sand is a proper material for building a reservoir embankment, certainly not in a great many cases. It might be suitable for building an embankment on a stream in the woods, or in some location where no damage would be done if the dam were carried away, or where there would be no damage done by any leakage through it, as in the case of the canal spoken of by Mr. Freeman. There would be liable to be a large amount of percolation when the reservoir was first constructed, which might afterwards be stopped by silting up. But surely in building a distributing reservoir for a city or town, as such reservoirs are usually built on hills, I don't think it would be proper construction to build the banks of sand.

In regard to the wetting of the material, I believe, with Mr. Noyes and Mr. Freeman, that the less water used the better. But in the case of the hard pan which we have in this vicinity, it would be in a great many cases almost impossible to make a compact bank without the use of some water. The hard-pan breaks up in lumps from 3 to 6 inches square, and it is very difficult to pulverize them, especially if they get a little dry and hard. But by using as little water as can be used to moisten the material, and then applying the material in layers not over 4 inches in thickness, and thoroughly rolling it, I believe you can obtain a very compact bank. That was the method adopted at Fisher Hill reservoir, and it might be interesting to know that the watering and rolling of the material placed in the embankment there, about 80,000 yards of material, cost about 2 cents a cubic yard, and the work was very thoroughly done.

MR. NOYES. I might add to what I have said, in answer to the criticism of Mr. Brackett. The engineer to whom I have referred was of course limited

as to the amount of money he had to expend, and I presume also he did not have the conditions which Mr. Brackett mentions, where there would be great damage done or danger to life from the giving away of the embankment, although he spoke very positively as to the efficiency of the work. I questioned him closely as to the probable filtration of water through the banks. He said that in no case had he found any evidence of filtration. I asked him if he did not in gauging or keeping the flow of the stream, or in any way, find that he lost an appeciable amount of water, enough so he could determine it by estimate. He said he did not, and had had no case where moisture had appeared below the bank, or where he thought there was any percolation.

Mr. Tidd. Mr. President, theory is one thing, and practice is quite another oftentimes. Now, I undertake to say that it is impossible to make a bank of clay or ordinary hard pan absolutely homogeneous and put it in dry. I don't believe it can be done. I have tried it several times and have found it needs a certain amount of water to dissolve it, as Mr. Brackett has said, especially any hard lumps. And the difficulty we had with the reservoir in Nova Scotia, where we had a stream come through the corner, was simply on account of the hard lumps which had not been wet enough to dissolve them and make the homogeneous with the rest of the material. Now the fact that you can pack dry material into a box and ram it down hard, and make the box hold more than you can if the material is wet, does not demonstrate that you can make a dam or reservoir embankment of dry material and have it tight; because you have the walls of the box in which to confine your material so you can pound it down solid. But if you take dry material and put it in a bank and undertake to roll it, as your roller passes along it will push the material ahead of it and force it out at the sides. I have tried it several times, times enough to learn that. If there is moisture enough to hold it and pin it down, your roller will then pass over it and put it in place, but if there is not the roller will push it ahead as I have said.

Speaking of sand embankments, I had occasion once to inspect a reservoir built at Platsmouth, Nebraska, at the mouth of the Platte river, by Mr. J. D. Cook, who has the reputation of being as good an engineer as we have, and it was built entirely of loose sand which was scraped up on the river flats in dry times. The idea was to build a settling reservoir, and to pump the water from the river into it to settle, the water to be pumped from there into a higher reservoir for distribution. I have no means of knowing what the result finally was, for at the time I saw it the river was low, and at times of high water it must flow within two or three feet of the top. There was nothing whatever used but sand, and I have some curiosity to know how the thing finally came out. It was built by a man whose reputation is as good as that of any engineer in the country. Of course the river is full of dirt and silt, and I have no doubt if the banks stayed there long enough to have this material filter into them they might be all right; but my idea of the thing was that the first freshet in the river would sweep them all away like a lump of sugar.

I have seen places on the banks of the old Middlesex Canal, which was used for fifty years, where they were built of loose gravel, and when they have been cut through in sections there appeared to have been no effort whatever made in their construction to make them tight, and yet they carried the water; but it was the water from the Concord river which carried with it a large amount of sediment, and the probability is that had filled the interstices and made the banks tight. I can easily conceive how that might be. I think we had a little experience of that in Brookline, as Mr. Forbes will remember, when they were short of water once at their filter gallery. They cut a trench along from the river parallel with their gallery, and led the water into it thinking it might filter through into the filter gallery. But that trench, as I remember it, declined to pass water through in about four or five days, and we had to rake the surface over every few days in order to get the water through. The material that came in the water of the Charles river, and which collected in the filter embankment, plugged up the bank so the water would not pass through it. The material that we raked off the bank resembled felt in appearance, and after it had been raked off it would allow quite a large flow of water for several days, and then it would close up again. That, I suppose, is the secret of the success of these embankments made of sand. If the water is clear and pure, like subterranean water, with no sediment in it, I doubt very much if a sand embankment could ever be made to hold it.

Mr. Darling. Speaking of the percolation of water through gravel, which my friend, Mr. Freeman, has referred to, I would say that in building what is known as the Diamond Hill dam, the ledge on each end of the artificial part comes up level with the top of the plain, as we call it. On the west side is a flat, level plain, consisting of material which is mostly coarse gravel and white sand. This plain extends from 400 to 800 feet behind the dam, and then comes the abrupt falling off down to the meadow bottom some 40 feet below. When we filled the dam to its full capacity there was a percolation that extended up the slope about 10 feet above the level of the meadow for some 400 feet in length, it wasn't of a magnitude that alarmed us, because of the thickness of earth behind the dam, and extending beyond the face of the dam some 200 or 300 feet. This percolation has kept receding since the dam was built, until now we cannot see any on the slope, showing that the silt, or whatever may have gone in there, has practically made the earth perfectly tight. I simply speak of this as a practical illustration of the effects of the filtration of water through earth embankments.

Desmond FitzGerald. The subject of reservoir embankments and earth dams has recently received a large amount of attention. It was discussed before the Boston Society of Civil Engineers in September, 1893. Having lately designed two high embankments for the storage of water for the City of Boston both between 60 and 70 feet in height and having devoted some time to the study of the theories and practices connected with their construction, it may perhaps prove of some value to some one if I give a condensed historical review of the evolution of earth dams and also a brief description of the dams above alluded to.

There have been many failures of reservoir embankments in England and as the experience of that country is covered by many generations, where ours extends only a few years into the past, let us take a glance first at English practice.

It may be said I think with truth, that very few embankments of proper slopes have ever given way under the pressure of water. They have generally failed : First, from insufficient waste way and, second, from the method of drawing out the water through pipes, culverts or tunnels.

The question of the proper design of spill ways does not enter into our inquiry as this subject has been fully treated elsewhere and the conditions for proper design are well understood by all hydraulic and water works engineers.

I will only say in passing that many failures of banks have been ascribed to defective outlets which have really been due to water overtopping the dam.

Assuming then that a dam has abundant length of overflow it is safe to say that the weak point is in the outlet.

In the embankments first built in England the pipes were laid through the artificial banks and the valves placed on the outside. Many failures occurred from the settling and fracture of the pipes under the weight of the embankments, and as there was no control to the water from the inside of course nothing could save the dam. This led to building culverts excavated in the hard ground under the embankments. In these culverts pipes were placed, with stop or cut off walls near the inner slopes. The valves were generally placed on the inside, either directly in line with the slope, or oftener in valve towers, of cast iron or masonry, connected with the tops of the dams by bridges.

The culverts have given way in most instances by settling under the weight of the embankment also by crossing the puddle trench or core of the dam without special precautions; and by having puddle placed around them. Puddle is a dangerous material to use where the heads are great. It is of course comparatively safe in the heart of an embankment but when placed around pipes or in a position where it can escape gradually under a small leak, it is to be used only with the greatest care.

The puddle trenches in most English dams are carried to great depths. Where the culverts were built across them the clay was very apt to settle and break the masonry. This led to constructing slip joints, which were clumsy contrivances and seldom successful, Afterwards it was found best to begin at the bottom of the puddle trench with masonry foundation and carry it up for the culvert to rest on. All these precautions however did not ensure success. In the first place the sinking of the trench for the core wall and the pumping of the fine materials out of the soil on each side of the centre line of the dam, is apt to disturb the ground and leave a poor foundation for the culvert. Several of the most eminent engineers in England have argued that the only safe way to take a pipe out from a reservoir is to drift a tunnel through the natural ground around the ends of the embankment, connected with a valve tower in the reservoir. The water can be taken either directly

into the tunnel or led out in pipes. Mr. A. R. Binnie, in a discussion before the Institute of Civil Engineers says: "By a tunnel outlet, he meant an outlet driven in the solid rock or shale, below the surface by mining either round the ends of the reservoir as in the case of the Stubden reservoir or passing deep into the solid rock or shale and below the bottom of the puddle trench as at Leeming and Leeshaw. By a culvert outlet he meant any brick or masonry work which was built under the embankment or in cutting which was afterward filled in and covered by the embankment." This engineer cites the failure of the Leeming reservoir as a case where the culvert was fractured at the puddle trench, although a slip joint had been used. The Leeshaw culvert with no slip joint was fractured under only 10 feet of embankment. The failure of the Vartry reservoir, in Dublin, in June, 1867, was due to water finding its way between the rock and the puddle which surrounded the outlet culvert.

Mr. Bateman, who had built more than a hundred reservoirs, great and small, said in the same discussion,* "But as to the proper mode of discharging water from reservoirs I am as uncertain as I was forty years ago. I have long ago abandoned puddle; in difficult circumstances I have no confidence in clay."

A. Jervis, another English engineer, contributing to the same discussion, thought the building of tunnels might be carried too far. The stratification might not be favorable for a tunnel. He suggested that a culvert built in an open trench along the side of the valley might be best, especially where the intersection with the puddle trench was in rock.

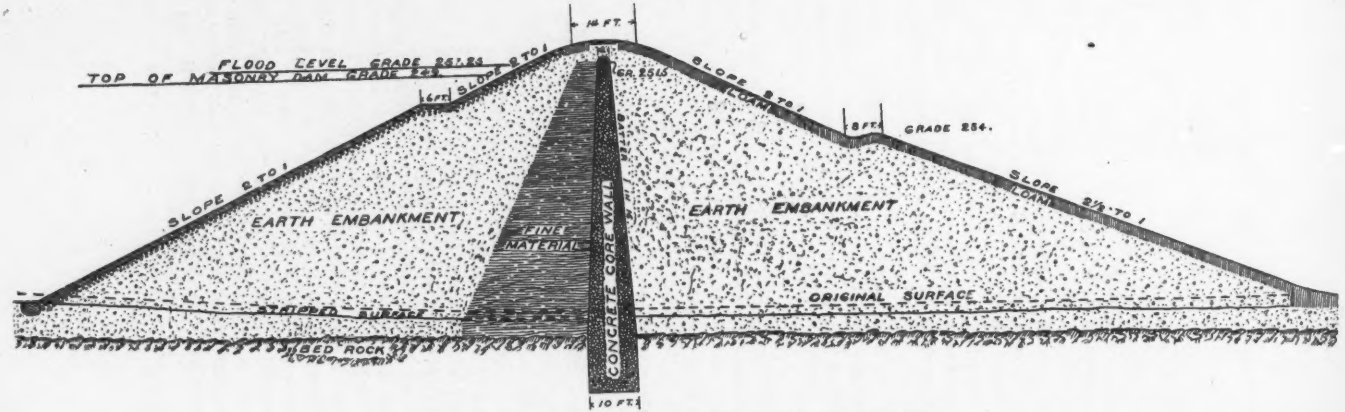
R. Hassard preferred where the ground was good, a culvert in deep trench on side of valley entirely under the puddle trench.

The failure of the Dale Dyke reservoir connected with the Sheffield Water Works is frequently alluded to in English publications. This embankment was 102 feet in height and it held 96 feet of water. It was poorly built and the pipes were carried through in a trench in the rock and surrounded with puddle. The valves were on the outside. Opinions differ as to the cause of the breach in the dam which resulted in the loss of 250 lives.

The almost universal practice in England is to build the inside slopes 3 to 1 and the outside slopes 2 to 1 and from observations of my own, particularly on Dam No. 4 of the Boston Water Works, I am inclined to believe that for high and important dams this is a good rule. It is almost needless to add that all pipes or culverts should be well provided with flanges and rings of masonry to prevent the water from creeping along the horizontal lines.

Allusion is frequently made to the old bunds in India and a word or two about these old dams may not be out of place. One of these forming the Cummins tank, consisted of an earth bank 102 feet high with 90 feet of water. The slope on the water side is 3 to 1 and on the outside $\frac{1}{2}$ to 1 at top and 1 to 1 on the bottom, revetted, These old dams, which have stood for centuries, were made by dumping small amounts of earth from baskets and

*Vol. LIX. M. Inst. C. E.



SECTION OF RESERVOIR EMBANKMENT, BOSTON WATER WORKS.

they were consolidated in some cases by elephants treading upon the earth. No core wall was used. It has been stated that India is full of irrigation reservoirs which have failed by water following the outlet sluices.

According to Humbert the width of an earth dam on top cannot well be less than 6 to 8 feet and it is frequently 12 to 20 feet.

I believe Mr. Rawlinson's rule was 30 feet wide at the flood water level and this gentleman's rule for puddle cores was that the thickness should nowhere be less than one-third the head of water.

Having given a summary of English practice, I will now state the practice on the Boston Water Works and some reasons therefor.

The plate accompanying this discussion shows a section of an embankment about 65 feet in height. The slopes are 2 to 1 on the inside a berme 6 feet wide about 8 feet below the flood level. These slopes are paved on a broken stone foundation. The slopes on the outside are 2 to 1 down to the berme, which is 20 feet below the top, and 2½ to 1 below the berme. These slopes are covered with at least 2 feet of loam. The site is stripped of all soil containing organic matter, and after the core wall has been started the bank is built up in 4" layers, watered slightly and rolled. The core wall is of concrete, plastered with Portland cement on the water side and with an occasional buttress on that side to stop the creeping of water lengthwise of the dam.

The core wall is carried to the rock 40 feet in places in the case of Dam No. 6, and is to be in a comparately shallow trench in the case of Dam 5, where the rock comes nearly to the surface.

Adjoining the core wall on the up stream side is placed selected fine and clayey material. The rest of the embankment is of gravel or whatever material may be convenient. The slopes however, both inside and outside should be of loose gravel to prevent the slipping on the water side when the reservoir is rapidly drawn down and to allow any leakage to pass freely away on the lower slope. This is an important point too often neglected. Where the material on the slope is of a clayey nature, a slide is apt to take place, sometimes taking the paving or rip-rap down with it to the bottom of the reservoir.

In considering the stability of this kind of an embankment, we must assume that the full head of the reservoir is carried to the core wall which is intended to be water tight. The material on the down stream side of the wall must then, by its weight, withstand the pressure of the water, besides a saturated prism of earth on the upper half. The factor of safety is about two, in the case before us, so that it would not have been wise to make the slopes any steeper on the down stream side.

There are several ways of solving the problem of building a high dam of earth work. If there is to be no core wall, then perhaps it will be safer to make a gigantic filter of the section, as has already been done in the case of some of the canal banks in India. The inner slope is made as tight as possible, next fine sand is placed, giving way to coarser and coarser material, until the outer slope is met, which is composed of a mass of rubble stone. The object of this arrangement is to provide for the safe passage of any leakage

from the inside to the outside of the embankment without carrying with it any of the material of which the bank may be composed. In the case of an important dam holding back a large amount of water, which might cause great damage if suddenly released, it has always seemed to me that no chances should be taken. If the puddle is placed on the inner slope it will take more of it to accomplish the same result than if placed in the centre of the dam on account of the longer line which it follows. Again, a large sheet of puddle is more exposed to changes of condition and it is more liable to crack and leak and certainly it is more liable to change its position by slipping.

One of the advantages of a masonry core wall is that no animal can burrow through it, and it is more difficult for any small leak to grow larger than it is in the case of clay puddle. In the section given in the accompanying plate it will be noticed that curved surfaces have been given to many of the exterior angles of the suction. They are more natural and easier to maintain than sharp corners, The berme, half way down the exterior slope, is introduced for drainage purposes, while the sod is forming. A gutter is formed in the berme, with slight slopes lengthwise of the dam leading to sod gutters running down the bank to keep the loam from being washed away by heavy storms.

In the case of Dam 6, the lower outlet pipe, 48" in diameter is laid in masonry on a rock foundation on the side of the valley. The core wall is carried over and around the masonry and besides these precautions, frequent cut off walls have been introduced along the line of the pipe. Another outlet pipe at a higher elevation is placed in a tunnel on a rock foundation at the other side of the valley. This pipe is placed in a tunnel because it is to be under pressure.

The valve towers or pits are of masonry and located just inside of the core wall which is continuous behind them.

In my own experience I have seen reservoir embankments fail which have never been alluded to in the public prints. It has occurred to me that some one anxious for a subject, for a thesis could not do better than to hunt up and describe accurately the conditions attending the failure of so many of our reservoir embankments, especially the details connected with the smaller reservoirs which have given way and which have never attracted public attention because they have been unaccompanied by loss of life or other serious damage.

I cannot agree with Mr. Taylor's statement that the tightest dams are those of earth. The tightest dams that I know of under great pressure have been carefully built stone dams.

In regard to what Mr. Tidd has stated about the dryness or wetness of materials I wish to say that it must be evident to all that there must be no lumps in the puddle or else it has not been thoroughly worked, but there is hardly any material which will absorb larger percentages of water than clay. If there is any chance for this water to drain off afterwards, immense cracks will result. The most satisfactory, solid and water tight puddle that we have used at Dam 6, has been that which contained the least water, but it must be

made perfectly homogeneous and thoroughly worked. In making a solid bank which shall be free from settlement, more depends upon the rolling and ramming than upon the watering.

We have built high embankments on the Boston Water Works which have not settled more than half an inch in fifty feet.

In building reservoir embankments an engineer must be guided by the local conditions and the resources at command, His design must be largely affected by the nature of his materials. There are certain general principles, however, which must be observed and which will be applied by an engineer of skill, judgment and experience to whatever design he may adopt. It is in the application of these principles that the services of the professional man become valuable, and it is from lack of them that there have been so many failures in the structures we have been describing

THE BURSTING OF THE PORTLAND RESERVOIR.

BY

JOHN R. FREEMAN, C. E.

(The President requested Mr. Freeman to describe the breaking of the Portland Reservoir.)

Mr. President, I will attempt to describe the accident very briefly. On Sunday morning the 6th of August, 1893, about 5.30 o'clock, the distributing reservoir of 20,000,000 gallons capacity on Munjoy Hill in Portland, Maine, gave away. It gave away without any previous warning. The Superintendent of the Water Works had visited the site within a very few days, and had been entirely around the embankment. Other men had also visited it within a comparatively short space of time, and there never had been a sign of the slightest degree of percolation anywhere, no rank growth of water grass, no damp spot or "spring" near the foot of the slope, although one part of the bank was 40 feet in height.

A man, whose house was demolished by the flood, testified that at 8 o'clock the previous evening he stood for some time leaning against the fence, scarce ten paces from where the break occurred, and his son who got home an hour after midnight noticed nothing wrong when he passed the spot.

The bank was built without a core wall, built of a material which, I should judge, was very much as Mr. Taylor has described as being used on the Lynde Brook reservoir.

The portion in the section indicated by the words "puddled bank" was from the natural clayey, gravelly, hardpan found on the spot, which was cut up, pulverized and compacted in 6-inch layers – well moistened and heavily rolled. Next the inside slope is shown, a puddle lining 4 feet thick which was an additional precaution to secure the greatest possible freedom from percolation—and consisted of an artificial mixture of about three parts of the natural crushed hardpan with one part of good blue clay, brought at considerable expense from across the back bay in the town of Deering. These were spread out in thin layers on a broad bed, mixed together thoroughly by Disc harrows, and then deposited in 6-inch layers and sprinkled, rolled and compacted like the rest.

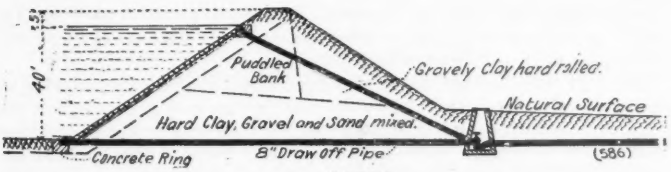
The portion marked "gravelly clay hard rolled" had no very distinct dividing line from the portion marked "puddled bank," but merely was the most pervious material and contained the natural loose earth on top of the hardpan mixed with a few chance cobbles of 2 to 4 inches diameter.

The natural substratum hardpan on which the embankment rested was as fine a natural hardpan as I ever saw. It was so very strong and tenacious that while the whole volume of that water was being poured out in a torrent over it, the hardpan proper was not cut into or washed away at any point to a depth of 6 inches. There was a trench cut down about 9 feet into the hard-

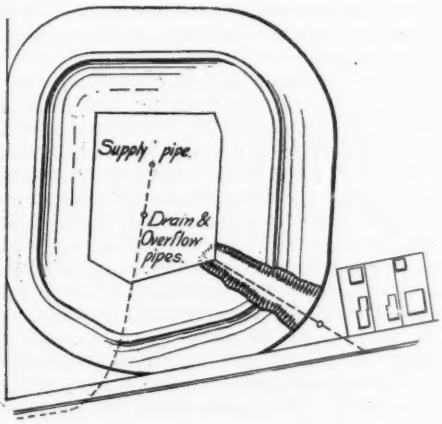
pan for laying the drain-pipe out from the reservoir, and after the washout the sides of that trench and the corners at the top of the bank showed almost as sharp and as clearly defined as on the day that trench was dug, while the first-class puddling material that had been compacted into that ditch was scoured out to a depth of perhaps 6 feet.

The break occurred at a point where the waste pipe, or the overflow-pipe, was laid out through the earth embankment. And in my judgment the break was due to the presence of this pipe.

Perhaps I had better first speak of how the break occurred, and what the



SECTION.



PLAN.

eye-witnesses say. At about 5 o'clock in the morning a woman, Mrs. Ellen M. Jones, who was visiting at a house very near the reservoir, was taking an early morning walk, accompanied by a little girl.

The little girl noticed a small stream spurting out of the ground at a point which appears to have been very nearly over the lower end of this waste-pipe, and said, "Look ! I have found a new spring." The elderly woman knew this stream meant something serious and with rare good sense ran to warn the

people who lived in two houses immediately down-stream. To her it is due that eight lives were saved. Had her warning been properly heeded no life need have been lost.

The progress of the break was very rapid. Probably when Mrs. Jones saw it first the hole was smaller than a man's wrist. Three minutes later, after she had aroused the people in danger, she found a "good large brook" coming through their door yard. Not more than fifteen minutes later the break had increased to a gap 40 feet across the top, two houses had been completely demolished—four people had been drowned—and the reservoir two-thirds emptied. The progressive character of the break was very interesting as described by the different eye-witnesses. The second person to see it called it big as a fire hose stream and thinks it issued from a place directly over the waste-pipe and 2 or 3 feet up from bottom of slope.

The next man described the water as spurting out of a hole "about as big as a man's leg;" a few minutes later there was another man got there, and his testimony at the inquest was that the hole was more than a foot in diameter and rapidly enlarging. And still another man who got there perhaps ten minutes after the first discovery, described the hole as being as large as a hogshead, and after that it increased very rapidly gullying out below, then caving down from above, forming a rude dam which soon cut out until finally a larger breakdown formed a barrier which held back the bottom 8 or 10 feet of the water in the reservoir and did not wash away.

The bank, so far as one can judge, from the testimony of those who built it, and from a careful examination of the ruins, was as thoroughly compacted and as well built as any one could ask for. From my careful examination of the ruins, I say without hesitation, a remarkably well built earth bank.

One thing which shows that the bank was put down in a good manner is that as this washout progressed the earth remained arched over the gap, until the gap had attained a width of perhaps 15 feet; that is, there was a hole at the bottom through which the water poured, and over which the upper part was continually crumbling in. The earth was so well compacted that it formed a natural arch over the hole, until the hole had got out to a width of perhaps 15 feet; and this arching certainly shows a good quality of earth-work.

Well, now, as to the cause of the break. As I have already said, there was a waste-pipe laid on a slope down through the bank, starting very near the high water line, and thence passing outward and downward on a straight slope through the bank. The overflow itself was formed in a block of concrete about 6 feet cube, and starting from that, an ordinary 12-inch bell and spigot cast iron tar-coated pipe was laid on a slope down through the bank.

There were no cut-off walls along this pipe. The pipe was laid by first building the embankment up all along, to a height of say 6 feet, just as though no pipe was there, rolling the 6-inch layers thoroughly meanwhile. Then, when all was ready to put in a pipe a sort of wedge shaped ditch was dug, which, at its lower end, was perhaps 6 or 7 feet deep with bottom sloping back up toward the inside at an angle of about 20 or 30 degrees and long enough to permit the putting in of one 12-foot length of water pipe.

After the lead joint was made in the ordinary manner, after plugging the upper end of the pipe to keep the dirt out, the men would puddle in around it very throughly with a mixture of nearly pure clay or of their best puddling material. After the ditch was thus filled up level they would treat the embankment as though there were no pipe there till they got up 6 or 7 feet more, and then dig out and insert another length of the cast-iron waste-pipe in the same manner as before.

After considerable investigation I came to the conclusion that there was no doubt that the break originated in connection with this waste-pipe through the embankment.

If there had been no waste-pipe there, I think there would have been no break.

Two or three things may have helped start the break.

First, this block of concrete at the head of the pipe had a nearly vertical face.

During the winter the ice, of course, was continually thrust against that block, and thrusting with almost irresistible force at times. As the water is frequently lowered a little and then rises again repeating this action again and again at different hours of the day as the influx and outflow vary, a sort of toggle-joint action of the ice against any vertical face of masonry may easily be produced.

Moreover, during the winter previous there was some very cold weather while the reservoir was drawn down nearly to its lowest level, and the embankment was exposed to very severe frost about Christmas time. You probably all have had experience with the effect of frost on a moist clay bank the inside lining of this reservoir was practically a moist clay bank. That moist clay bank would heave under the influence of the frost, and that would also lift with great force against the 36 square feet of area on the level bottom of this concrete block.

Since this block was firmly built on to the pipe, the pressure against this block, prying away at the end of the pipe, would have something the same effect as when you have a crow-bar run into a bank of earth and pry away at the end of the bar; you will loosen the earth immediately around the bar where it enters the bank.

Here I think it likely that some similar action occurred in loosening the earth a very little, from its close contact with the upper end of the pipe, perhaps the crack was not thicker than a sheet of paper around the upper part of the pipe.

Then there is another thing which I think may have had some influence. The puddling material around this pipe was put in rather more moist than the material in the rest of the bank.

If there was an excess of water used there, there naturally would be a slight tendency to shrinkage after that excess of water got more evenly distributed through the rest of the embankment, and as that shrank there would be a tendency for the earth to grip the pipe a little less securely than it did at first.

Very many of you have had forced on your attention the great tendency of water to follow along a smooth iron pipe. This is found on pipes sloping down a hill in wet ground and I have often seen it follow along iron water wheel penstocks.

I think it was a fatal oversight not having cut-off walls along the pipe.

I will take time only to suggest one other point, on which some of the other members may bring valuable information to bear, and which has just been suggested in what I said about this puddled trench around the pipe having been put in a little more moist than the rest of the embankment.

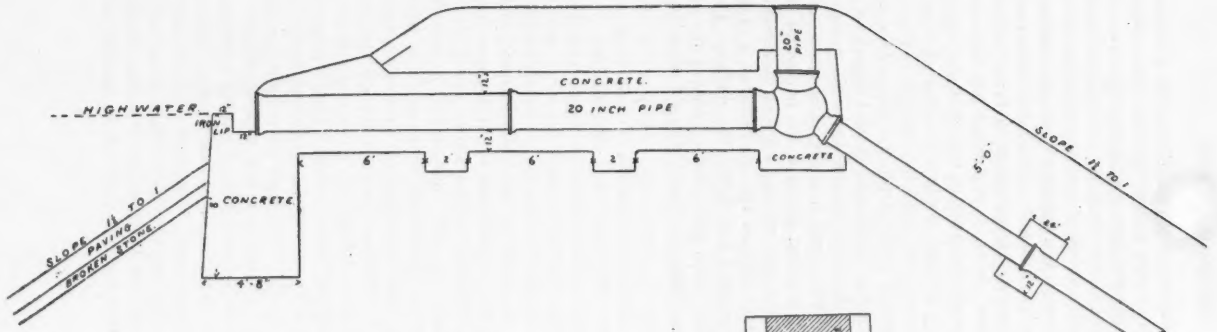
The question is whether one can make a tight embankment better by putting the material down wet or putting it down dry. Some experiments that our fellow member, Mr. FitzGerald made at Chestnut Hill some years ago, are very instructive as to what happens if earth is compacted in a moist condition. He desired to fill a box, (which, as I remember it, was some 6 feet cube) with earth as compactly as possible. He found that when he puddled the earth into the box and then left it exposed to the atmosphere, there was a shrinkage of the earth, that it shrank away from the sides of the box nearly a quarter of an inch when it became thoroughly dry; and he found he could get a greater amount of earth into this box—could get it in so it would hug the sides more closely, by ramming it in a dry condition than he could by putting in water and puddling it and pounding it down. This is quite a fruitful topic for discussion, and so with its suggestion I will close.

DISCUSSION.

Mr. Fuller. I would like to ask with regard to this Portland reservoir, whether the waste pipe could not have been carried out in the same trench in which the inlet pipe was laid? And, also, whether it would not have been better if the waste pipe had been carried out from the gate-chamber, in which case there would have been no trouble from the ice.

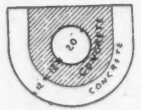
Mr. Freeman. There was no gate chamber there. The inlet pipe came in on one side of the reservoir and rested down on the natural hardpan. The outlet pipe went out at the other side, and that also rested on the hardpan. Those were on the up-hill side of the reservoir, however, and the natural place for pipes for taking off the overflow and for draining the reservoir to the very bottom was on the other side of the reservoir where the ground was lower.

Mr. Tidd. I consider that a pipe like that mentioned in the case of the Portland reservoir, is a very dangerous thing to put in. I may have done many risky things, but I don't think I ever did that. I think Mr. Freeman has given the practical solution of the difficulty in Portland. There can be no doubt in the mind of any engineer but that the pipe must have been lifted by the frost, as he says; for the ice pushed fearfully hard, and sometimes it falls below, as he says, it drops into a V, and when it returns again it opens the other way and causes a great pressure. And there is no doubt in my mind that it moved the pipe enough to leave a chance for the water to start down through there.



OVERFLOW PIPE AS REBUILT

SCALE 8 FEET TO AN INCH



SECTION ON LINE A

Mr. Brackett. In continuation of the description Mr. Freeman has given us of the Portland reservoir, it may perhaps interest you to know how the break was repaired, and what means have been taken to prevent a recurrence of the same accident. In repairing the break, the material on the sloping sides of the break was very carefully removed to a sufficient distance to be sure that no incipient cracks might be remaining, and then it was very carefully replaced in thin layers. Perhaps I ought rather to say that this is the method which was recommended by the engineers who examined the break for the Company; this is their recommendation, which I understand has been carried out. But, as Mr. Freeman has stated, the cause of the break was supposed to be the waste-pipe, which, in the original construction, started from a quarter turn set in a concrete block and went down through the center of the bank. In repairing, a block of concrete 8 feet in depth was put in deep enough to go below the reach of the frost, and a 20-inch pipe carried horizontally, or with a very slight pitch, across near the top of the embankment, surrounded on all sides by concrete with cut-off walls; and near the outer side of the embankment a pipe is carried up, permitting access to the horizontal 20-inch pipe so that it can be examined at any time and any signs of movement detected. From this point near the outer side of the embankment, a 12-inch pipe is carried down the outer slope about 4 feet below the surface. The embankment has been widened at this point, which was a corner of the reservoir, so that the new drain is entirely outside the lines of the old embankment.

A CHEAP COVERED RESERVOIR,

BY

JOHN C. CHASE, Superintendent, Wilmington, N. C.

[Read Jan. 10th, 1894.]

The remarks made by Mr. Noyes at the last meeting of the Association relative to the variation in the dimensions of details as affecting the cost of engineering works designed for the same general purpose and where supposably the same general conditions existed, variations caused perhaps by the different ideas of the engineers in charge, or perhaps on account of the limitations of the location, suggested that a description of a cheap covered reservoir with detailed cost of construction might be of interest.

The city of Albany, Ga., derives its water supply from artesian wells, but the hourly flow not being equal to a possible maximum hourly draught, it became necessary to provide for a storage of about 250,000 gallons. The city lot on which the pumping station and water tower were to be erected had a frontage of only 105 feet, with a depth of 210 feet, and with this limited area it was decided to build a circular basin 60 feet in diameter with a depth at the side wall of 13 feet, the bottom having a uniform slope of one foot to the center. On account of the expense of disposing of the material excavated, the structure was built only about one-half in excavation. The excavation was in a very compact red clay, so hard in fact that the city in building cisterns 15 feet deep and 18 feet in diameter for fire-engine supply, have merely plastered the vertical side of ths excavation with hydraulic cement mortar, using a brick dome of about five feet rise for covering.

In this hard material it was practicable to build a very light lining wall of 16 inches in thickness, which rested on a slight footing course about 8 inches below the bottom of the reservoir. The excavation was cut out very carefully about one-half inch larger than the exterior of the wall. In laying the brick, Portland cement was used for the inside course, and Rosendale for the other three courses, and the half-inch space outside of the brick-work was flushed full of cement, so that practically it is earthen well lined with brick. The wall was carried about 6 feet above the natural surface of the ground and received a coating of cement mortar on the outside. The excavated material was filled back against the wall, being deposited in layers, dampened and thoroughly rammed. The filling was carried to a point one foot below the top of the wall and finished with a berme of four feet and a slope of one and one-half to one. The lining of the bottom was a course of brick set on edge in a bed, and with a joint of Portland cement mortar. It was intended to cover the interior surface with a coating of Portland cement grout applied with a brush, but through some misunderstanding it was plastered with Portland cement mortar $\frac{1}{4}$ inch thick. The character of the water was such that it was necessary to exclude

the sunlight, and a wooden roof seemed to be the cheapest and most feasible device. A brick pier 20 inches square was built in the center of the reservoir which carried one end of twelve principal radial trusses with 8 feet rise, made of 1½ inch by 10-inch yellow pine plank. The chords and rafters were made up of two thicknesses of plank, separated by the diagonal members, the whole being securely fastened by bolts and spikes. The covering was of ¾-inch weather boarding 9 inches wide and laid 6 inches to the weather. The butt joints at the ridges over the trusses were covered with a flashing of tin as each course of the weather boarding was put on and on completion the roof received two coats of mineral paint. It is designed to cover the roof with metal when the present covering begins to show signs of decay. The roof is surmounted by a hexagonal cupola, with suitable openings to it, and also at the eaves, for ventilation, which are protected by galvanized wire screens. The roof water falls from the eaves into a shallow paved gutter and is carried down the bank by three lines of 6 inch drain pipe, in order to preserve the slope. The supply from the wells is carried over the top of the wall and a suitable overflow pipe provided. Also a drain pipe, which starting from the center will permit of entirely emptying the reservoir. The pump supply is drawn from near the bottom and on the opposite side to the inflow pipe. The reservoir has been in use some fifteen months and is believed to be thoroughly water tight. It has been filled and emptied several times, and has shown no signs of bulging or distortion. and with the precautions taken to prevent surface water from finding its way down behind the wall, and to keep the contents from leaking out, it is hard to conceive of any hydrostatic pressure ensuing, tending to rupture the sides or bottom. The detailed cost is as follows:

101,500 Brick, at $4.75	$482.63
78 Bbls. Portland Cement at $2.90	226.20
51 " Rosendale " " 1.65	84.15
103 Loads of Sand " .50	51.50
Labor of Excavating and Bricklaying	611.88
Incidentals	12.00
Contract for Roof, complete	309.00
Total,	$1,777.36

The work was all done by the day excepting the roof, which was contracted for. The prices paid were, for unskilled labor $0.75; masons, $3.00; foreman, $4.00 and the days work averaged about eleven hours. This fact and the low price of brick will account in part for the low cost of construction. Snowfalls being very light and infrequent, permitted a much lighter roof construction than would be possible in less favored localities. The full capacity of the reservoir is about 280,000 gallons.

A METHOD OF RECORDING THE LOCATION OF WATER MAINS AND SERVICES.

BY

GEO. A. KIMBALL, Civil Engineer, Boston, Mass.

(Read Jan. 10th, 1894.)

This method was adopted for recording the location of water mains and services in the city of Somerville about fifteen years ago and is still in use. Ordinary field note books are used, each book containing a certain district of the city. The pages of the book are divided into $\frac{1}{4}$ inch squares for the purpose of laying off the distances substantially to a scale. The street is drawn down the middle of the page and continued on the next pages until it is finished. The arrows indicate corresponding points on the pages. On each side of the street are drawn the houses, fences and other structures. In the streets are shown the mains, water services, gates, hydrants, all of which are laid off to a scale by using the squares. Measurements are taken to the pipe from the buildings and other permanent structures. Main pipes are laid one-third the width of the streets from the side line.

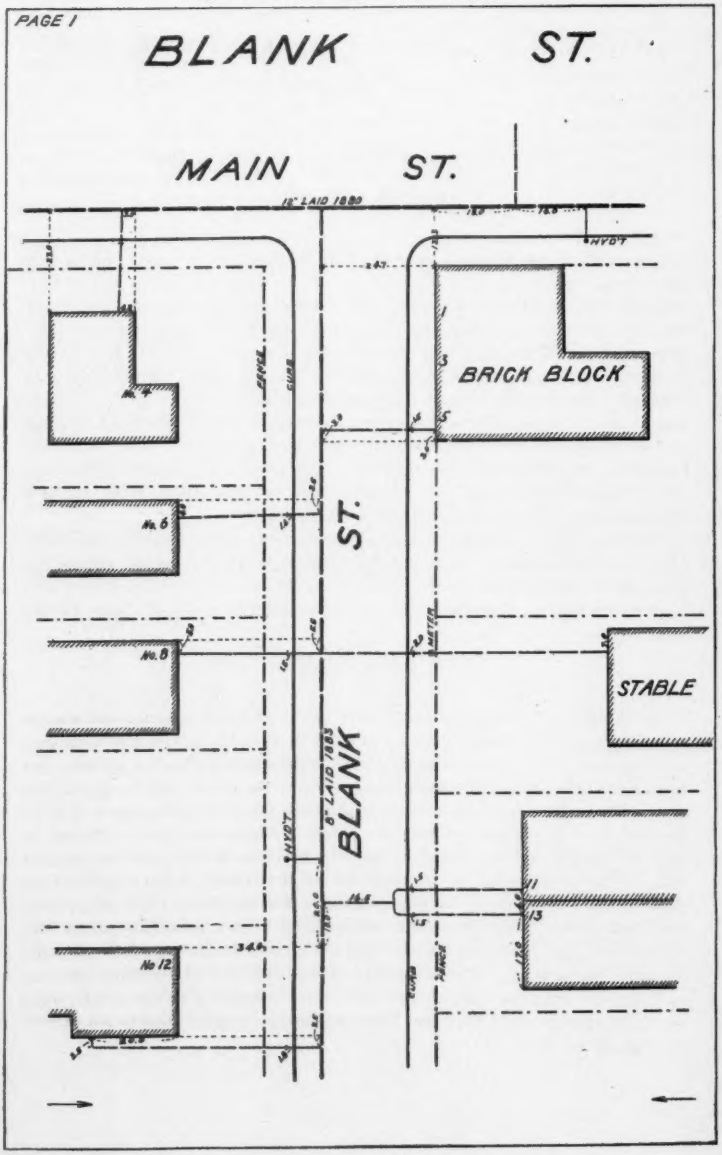
The advantages are that the books contain a complete record of all water pipes and connections. They can be referred to quickly as the streets are arranged in alphabetical order. The books can be carried in the pocket and used on the ground if desired. The following page is a sample page in the note book.

DISCUSSION.

MR. FULLER. I would say that I have followed a system somewhat similar to this, except that I have made it a practice to keep the service pipe locations in a separate book. In locating and showing the main pipes, my practice has been to make sketches on tracing cloth, showing the pipes with the gates, and then make enlarged sketches to show the location of the gates more clearly. I would have the distances, from the houses, perhaps every 50 or 100 feet, so that the pipe could be located in case the location of the pipe was wanted when sewers were put in, or anything of that kind. I have made these sketches on tracing cloth, perhaps a sheet 3 feet square, divided off, so that after taking blue prints from this tracing I could bind these blue prints into book form, and still preserve the original sheets on tracing cloth with the locations upon them. The advantage of this is that if the book is lost you still have the originals, and all you have to do is to take the blue prints, copy off the sheets and bind them in a book, so that the original book is not carried into the street at all.

LOCATION OF WATER MAINS AND SERVICES

SAMPLE FROM PAGE OF NOTE BOOK



MR. HARRINGTON. In Cambridge, and I suppose it is the same in most cities, the information that is wanted on the street, is the location of the gates and pipes. We have a book, which is perhaps one-third the size of the one Mr. Kimball has shown, which shows the location of the gates and the pipes, and the measurement to them. The two locations are mainly at right angles from the line of the street. In that way we get all the information we want on the street. The other information with regard to the supplies and the other things which Mr. Kimball may have in his book, is wanted quite frequently and more generally in the office, and that we have on a separate book, dividing the city into districts. It seems to me the measurements ought to be taken from the fence line, or the line of the street, for we find in Cambridge the houses are moved frequently, thus throwing the measurements out entirely.

MR. BRACKETT. It is a good plan to locate pipes and gates in such a manner that they can be easily found without reference to records or plans. With this end in view, pipe should be laid at regular distances from the lines of the streets and gates located opposite the lines of cross streets. Every branch from pipes twelve inches in diameter and larger should have a gate at the connection. These rules cannot be followed in all cases, but when adopted as far as possible they will greatly simplify the system.

Record plans showing all pipes, gates and hydrants on a scale as large as 100 feet to an inch should be made and frequently corrected to show all additions or changes in the system.

In Boston, detail drawings of all important or complicated connections, giving locations of gates. are made on sheets $3\frac{1}{2} \times 6$ in and bound in pocket book form for ready reference.

The point which it seems to me should be impressed upon all superintendents and engineers in charge of water works, is the necessity of always keeping a careful record of all work done, in such a manner that it can be conveniently referred to at any time. The tendency in many cases has been to keep all of the records in the brain of the superintendent, a very unsafe practice.

OBITUARY.

ROBERT K. MARTIN—Chief Engineer Water Works, Baltimore Md. Died November 24th, 1893, aged 58 years. Joined this Association, June 13th, 1889.

Mr. Martin was Chief Engineer and designer of the Druid Hill Reservoir, the High Service Reservoir in 1871 and the Gunpowder River Supply Works, including the big tunnel commenced in 1875. He was connected with the Baltimore Water Department for over 37 years and was its executive official for nearly 30 years. He took a high rank as a consulting engineer and was offered the position as consulting engineer by the New York authorities in the matter of construction of water works.

EUGENE P. LEBARON—Chairman Water Board, Middleboro, Mass. Died December 1st, 1893. Joined this Association, February 12th, 1890.

Mr. LeBaron acceptably filled many positions of trust and confidence as well as the one above mentioned, and enjoyed the respect and confidence of his fellow citizens to a marked degree.

TRANSACTIONS AND JOURNAL

OF THE

New England Water Works ASSOCIATION.

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TRANSACTIONS, 1883–1885.

JOURNAL, VOLUMES I TO VII INCLUSIVE.

COMPILED BY HENRY N. OGDEN, C. E.
REVISED BY DEXTER BRACKETT, C. E.

Articles in the TRANSACTIONS are indicated by year and page.

Articles in VOLUMES I and II of the JOURNAL are indicated by volume, number and page.

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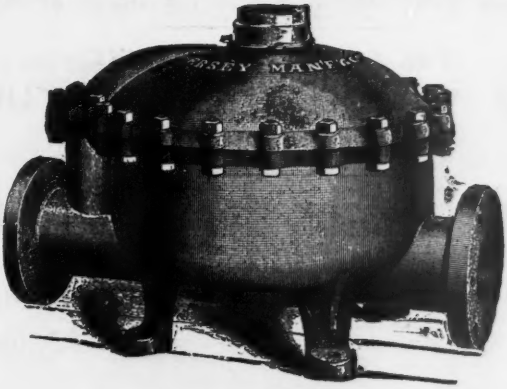

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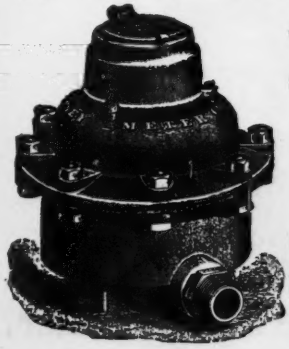

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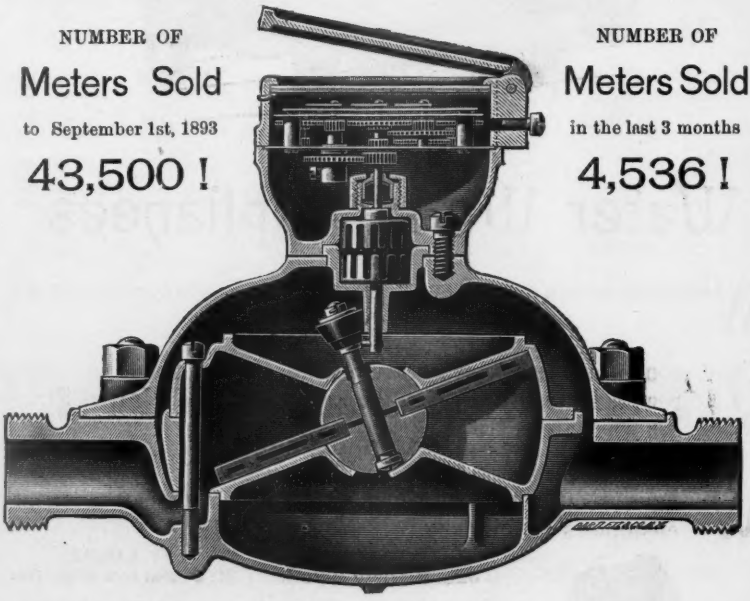

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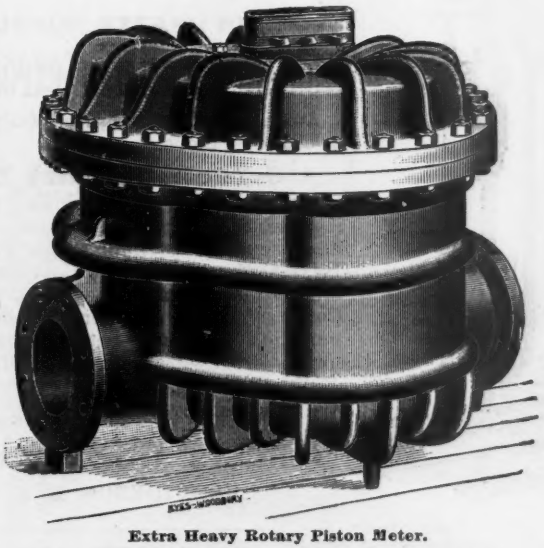

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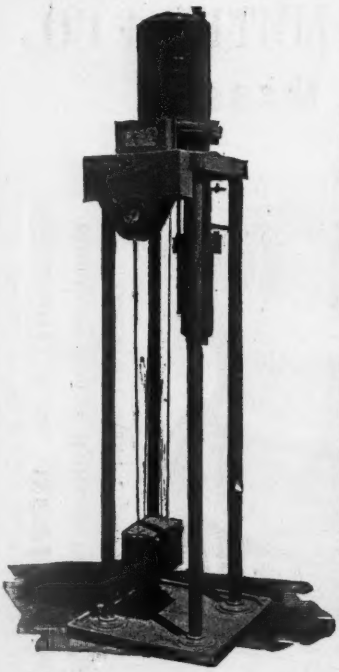

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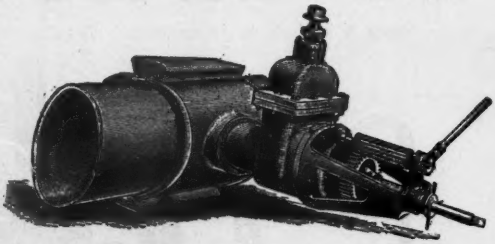

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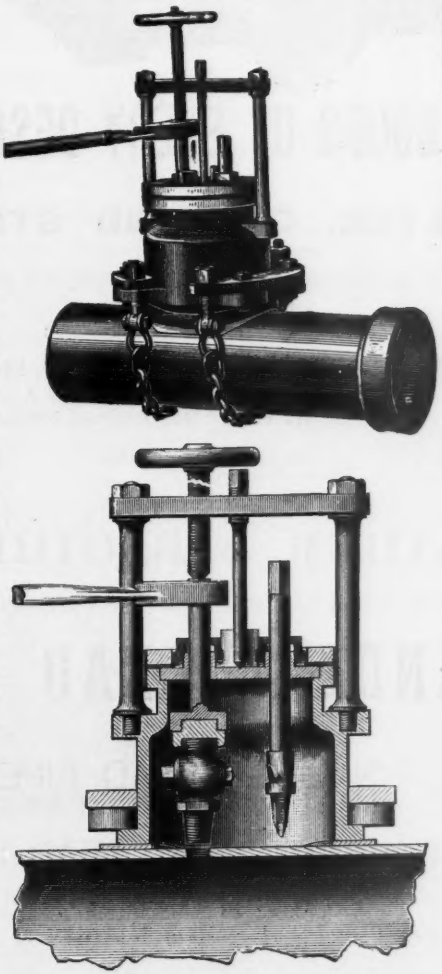

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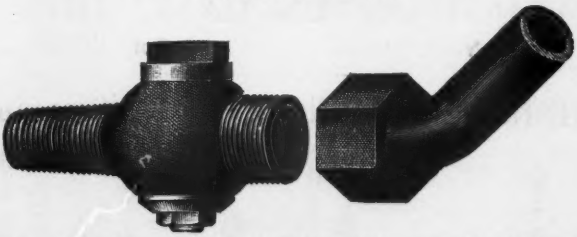

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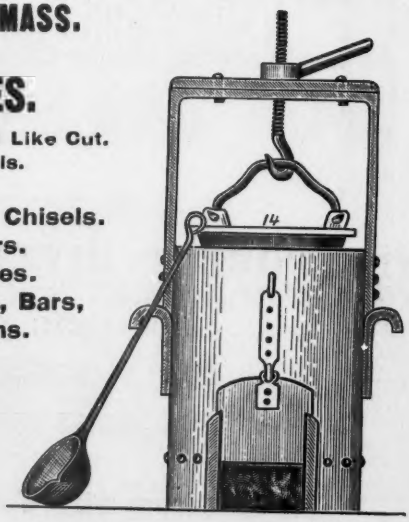

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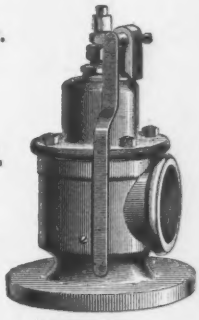

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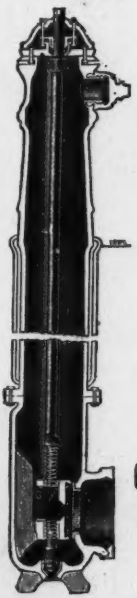

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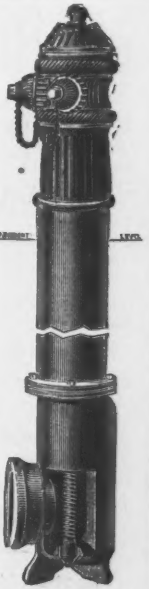

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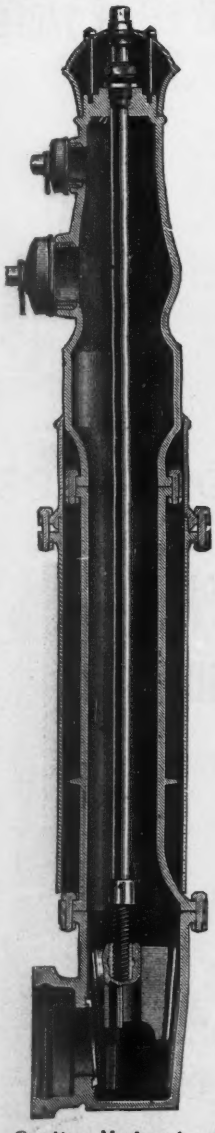

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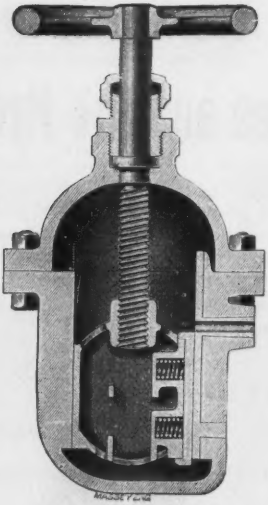

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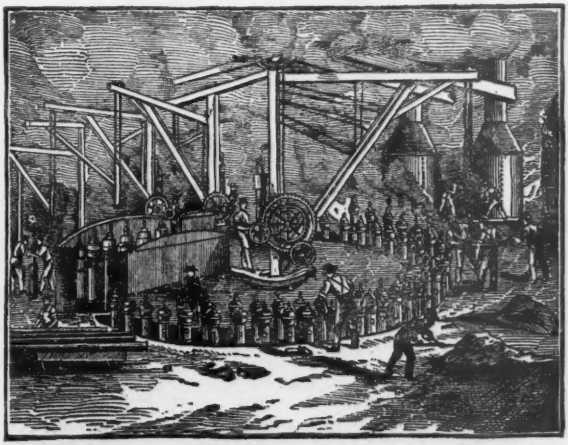

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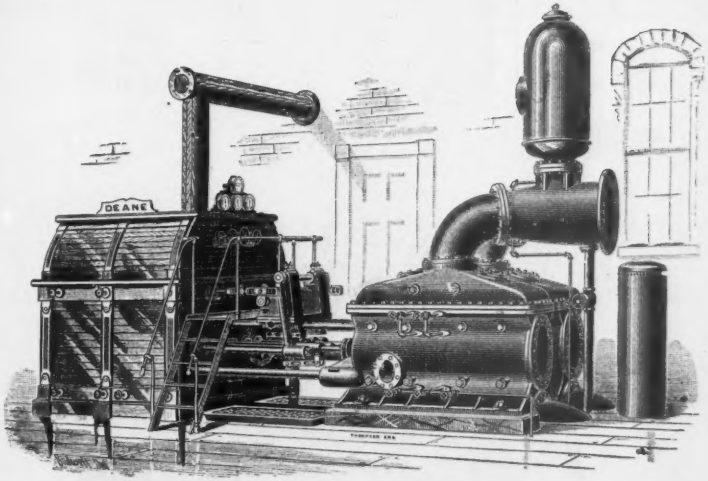

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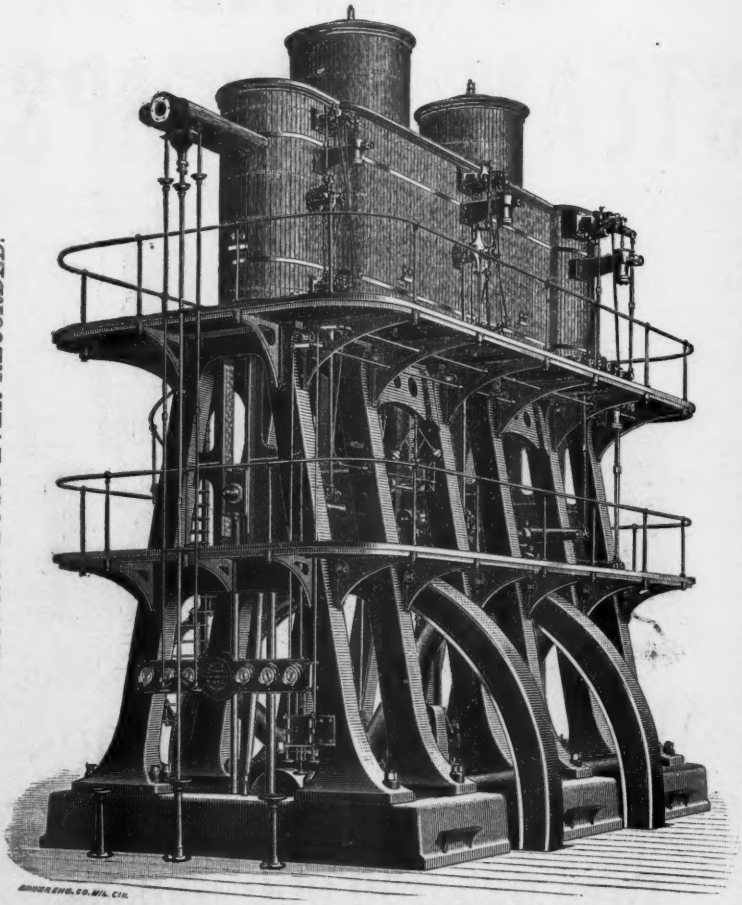

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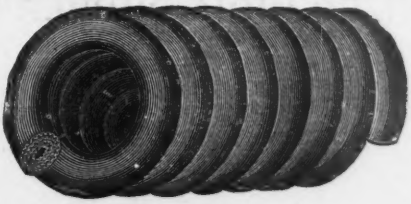

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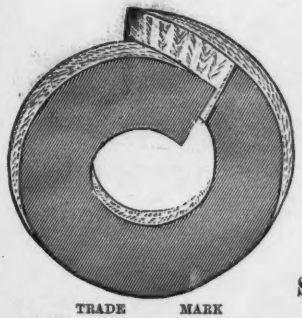

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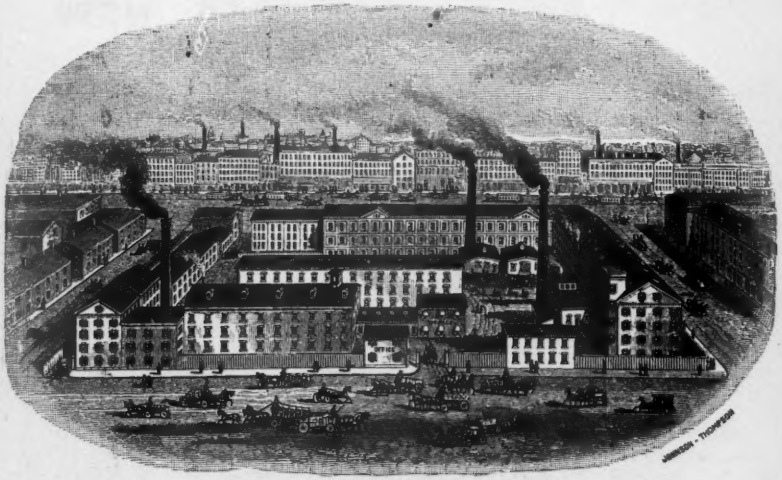

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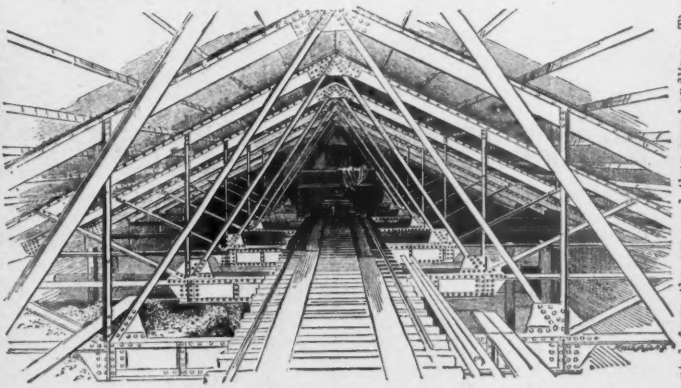

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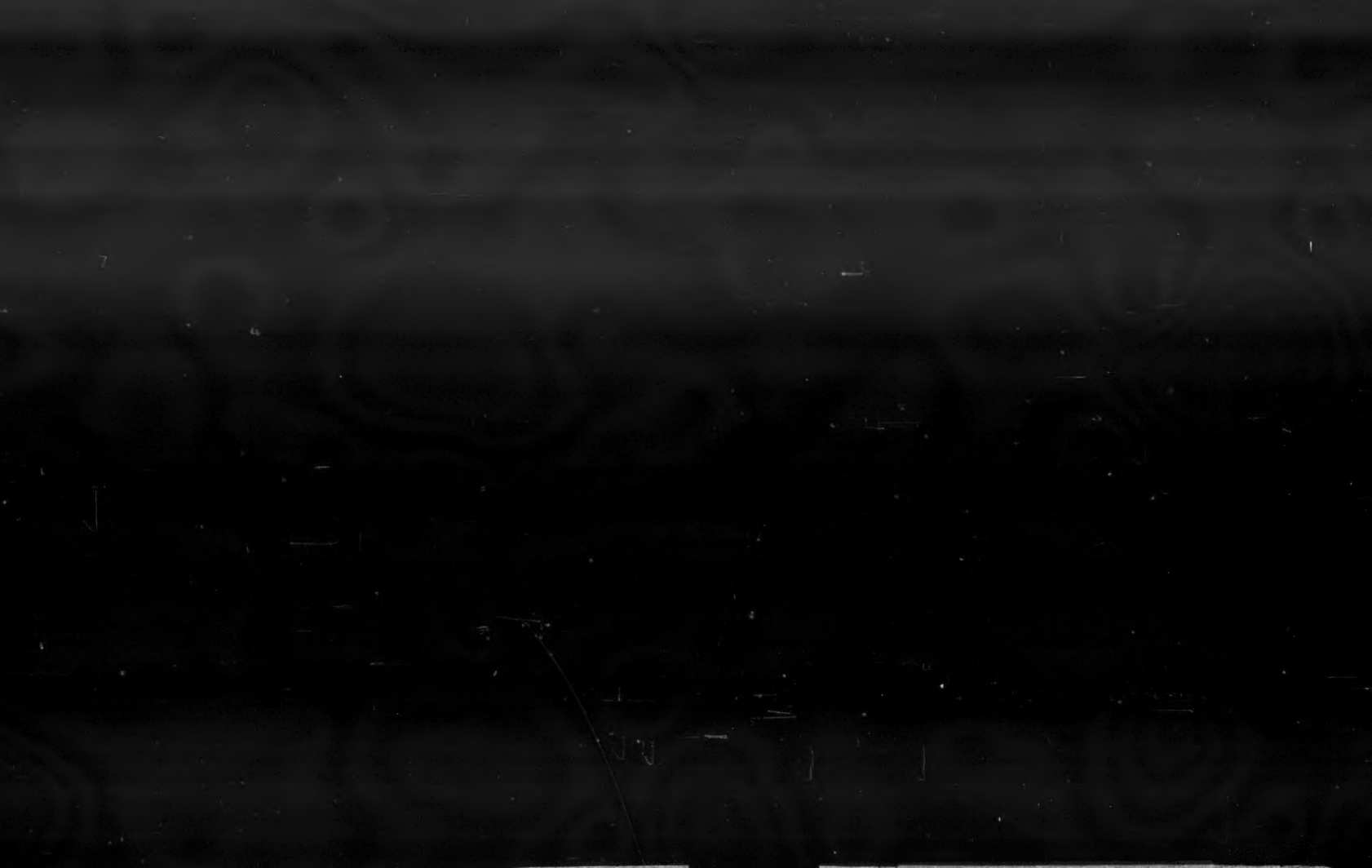
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